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European Agency for Safety and Health at Work

Biological agents and prevention of work-related diseases: a review

European Risk Observatory

Report

European Agency for Safety and Health at Work

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Abstract

A subset of all microorganisms cause disease(s) in humans (pathogens), and the health effects caused by biological agents have a major impact on public health. Worldwide, an estimated 320,000 workers die annually from work-related infectious diseases, 5,000 of whom in the EU. More insight into and awareness of biological risks is therefore vital for a detailed evaluation of these health effects, including those of combined exposures.

This 'review on work-related diseases due to biological agents' project, commissioned by EU-OSHA, intends to provide insight into the problems and to provide information about health effects related to biological agents for policymakers, actors in occupational disease monitoring and recognition, actors at the enterprise level and those in sectoral organisations. The report presents the results of the review, including information on emerging risks, monitoring systems and examples of prevention measures. The views of different parties, workplace practitioners and experts (based on interviews and focus groups), and their converging and diverging views, were included. As biological agents are widespread, several sectors were addressed more specifically: animal-related work, waste and wastewater treatment, healthcare, arable farming, and occupations that involve travelling or exposure to travellers.

Recommendations at the European level from the project include harmonisation of monitoring systems with regard to collection of data, the need for better implementation of policy measures to increase their effectiveness, more knowledge exchange, developing reliable and standardised measurement methods for exposure to biological agents, and suggestions for changes in the EU Directive on biological agents. At the national level, the visibility and the approachability of experts should be improved, and the importance of dealing with the workplace risks from biological agents and awareness raising should be emphasised. At the sector and company level, wider approaches for sector-transcending risks and process approaches with a broader scope and higher level solutions should be implemented. An approach similar to a lifecycle approach in chemicals management could be adopted that includes all steps and tasks of a worker (locally), seeing all possible risks that the worker encounters. A combined risk approach (taking a broader scope and including more (diverse) risks (biological risks, physical risks, chemical risks, and/or risks from biological agents) would emphasise the importance of workplace risk assessment. More general, broader prevention policies and measures that also protect workers from exposure to biological agents should be implemented to tackle unintentional exposures.

Executive summary

This project, commissioned by EU-OSHA, intends to provide more insight into the health problems encountered by workers that are exposed to biological agents and the challenges for their employers. It also aims to provide information on structured approaches to recognising and preventing the effects of biological agents that may support the work of policymakers, actors in occupational disease recognition and reporting, actors at the enterprise level and those in sectoral organisations.

Definitions and scope of the project

Directive 2000/54/EC on the protection of workers from risks related to exposure to biological agents at work defines 'biological agents' as *micro-organisms, including those which have been genetically modified, cell cultures and human endoparasites, which may be able to provoke any infection, allergy or toxicity.* It goes on to define 'micro-organism' as a *microbiological entity, cellular or non-cellular, capable of replication or of transferring genetic material.* This research project uses a wider definition of biological agents, namely: *microorganisms and carriers of plant or animal origin that can cause adverse health effects in workers, and that can be divided into two groups: living (micro)organisms (such as bacteria, viruses, fungi, yeasts and prions) and substances or structures that originate from living or dead organisms (such as exotoxins, endotoxins, glucans, mycotoxins and allergens).*

Only a small subset of microorganisms – pathogens – cause disease in humans. Health risks related to biological agents occur in all kinds of circumstances and (occupational) environments.

Project design

The project consisted of five tasks that feed into each other:

1. literature review on specific work-related diseases (WRDs) due to biological agent exposure and review of selected monitoring systems, complemented by a stakeholder survey;
2. structured interviews with experts on their views on policy and practices;
3. focus groups with workplace intermediaries;
4. a stakeholder workshop in which the intermediate findings of the research were presented and commented on;
5. final report summarising the abovementioned tasks, including policy recommendations.

The various tasks provide an overview of what is known from literature and practice on health effects of biological agents, sectors and occupations at risk, and policy and prevention measures in selected sectors. Together this enables an assessment of the discrepancies and similarities between research, policy and current practices, showing the gap between what is known from research on biological agents and the risks they pose and what is currently done to prevent exposure to biological agents (policy and practices).

This report (task 5) presents the summary of the integrated tasks 1 to 4 and provides policy recommendations that decision makers can consider for improving the prevention and control of the effects of biological agents at the workplace.

Methods

Literature review (task 1)

The aim of the scientific literature review was to identify and summarise existing reviews on biological agents and adverse health outcomes and studies on monitoring systems, databases and the provisions of EU Directive 2000/54/EC([1]). An extensive search was carried out in databases containing both scientific literature and grey literature. In addition to the literature search, a stakeholder questionnaire was developed to gather information on data sources that help target the prevention of diseases and emerging risks caused by biological agents and monitoring systems of exposure and disease. It also collected the views of the stakeholders on priorities for research and prevention, as well as information on campaigns, prevention programmes and particularly interesting case studies or smaller outbreaks of diseases linked to exposure to biological agents. The questionnaire was distributed among members of EU-OSHA's network of focal points, the European Foundation for the Improvement of Living and Working Conditions' (Eurofound's) European Observatory of Working Life (EurWORK) ([2]), the Partnership for European Research in Occupational Safety and Health (PEROSH) ([3]) and Modernet (Monitoring trends in occupational diseases and tracing new and emerging risks in a network) ([4]). The questionnaire also supported the selection of national monitoring systems from Denmark, France, Germany, the United Kingdom, the Netherlands and Finland, for further exploration and comparison. The literature review was published by EU-OSHA in 2019 (EU-OSHA, 2019a). It provides an overview of the most relevant biological agents workers are exposed to and the resulting health problems, including extensive overview tables of the most relevant agents and diseases in different occupations

([1]) Directive 2000/54/EC of the European Parliament and of the Council of 18 September 2000 on the protection of workers from risks related to exposure to biological agents at work (seventh individual directive within the meaning of Article 16(1) of Directive 89/391/EEC).

([2]) EurWORK gathers all Eurofound's resources on working conditions and industrial relations, and is supported by a network of European correspondents across all EU Member States and Norway. Eurofound runs two regular surveys on working life issues — the European Working Conditions Survey (EWCS) and the European Company Survey (ECS) — which are another major resource for the observatory.

([3]) PEROSH partners aim to coordinate and cooperate on European research and development efforts in OSH. The network comprises 13 OSH institutes, all of which play key roles in their national affiliations to governments/authorities and health and accident insurance systems.

([4]) Modernet was founded in 2008 as a collaboration between academic centres investigating occupational disease and work-related ill health incidence in a few EU Member States. Between 2010 and 2014, the network grew to include 12 more European countries and one institute from Australia.

and sectors. It also explores the allergenic effects of biological agents and provides an in-depth insight into the monitoring systems from the above-mentioned sectors and conclusions and recommendations for monitoring of exposures and disease.

Semi-structured interviews with experts on policy measures (task 2)

A total of 25 interviews were conducted with experts from Denmark, Finland, France, Germany, and the Netherlands to obtain their view on policy and existing policy measures in their country for five groups of high-risk occupations (animal-related occupations, waste and wastewater management, health care, agriculture and occupations that involve travelling and contact with travellers). The interviews were semi-structured and conducted either online or face-to-face. To make sure that the experts had the same starting point, an introductory document clarifying the definitions and concepts used during the interview and providing a list of examples of OSH policy was sent to them in advance. Five experts per country took part in the interviews, resulting in a total of 25 interviews. The interviewees were from different fields and disciplines, and worked in research, policy and practice, and consultancy.

Focus groups (task 3)

The objective of the focus groups was to learn from the experience of intermediaries (OSH service providers, labour inspectors, safety technicians, occupational health services, trade union representatives, etc.) to identify specific upcoming risks and any lack of measures regarding work-related diseases due to biological agents, and to address the possible need for additional measures. A total of 39 experts participated in the focus group discussions held in Denmark, Finland, France, Germany and the Netherlands. Many experts were familiar with biological agents in more than one sector, and thus able to participate in discussions on topics from different sectors.

Stakeholder workshop (task 4)

The goal of the stakeholder workshop was to inform stakeholders of the project's (intermediate) main findings, and to enable a discussion (on a policy level) with relevant experts and stakeholders on what could be done on both the European and national level to (better) control the risks associated with exposure to biological agents in the workplace. The participants had received the draft final report and discussion questions beforehand. In total, 37 persons (from Austria, Belgium, Bulgaria, Croatia, Denmark, Finland, Germany, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Norway, Portugal, Romania, Slovenia, the Netherlands, and the United Kingdom) attended the workshop. During the workshop, the (intermediate) main findings (tasks 1-3, including emerging risks, monitoring systems and options for policy measures) of the project were presented. Furthermore, a representative of the European Commission provided information on the results of an evaluation of the EU OSH acquis and proposals for amending Directive 2000/54/EC. A representative of the German Committee on Biological Agents presented on the national policy framework on biological agents in Germany. A representative from France presented on a national monitoring approach addressing emerging diseases in France, and a representative from Finland presented a national prevention policy approach (the farmers' occupational health services (FOHS)). The presentations were followed by group discussions and a plenary discussion in which the outputs of the different discussion groups were summarised. The discussion topics were 1) monitoring of diseases due to biological agents and exposures to biological agents, 2) policies and practices in place for managing and controlling exposures to biological agents in the workplace, 3) specific sectors and groups, and 4) EU directive on biological agents.

Results

Based on the outcomes of the literature search and the interviews, five groups of high risk occupations were identified and more information was collected on these sectors: animal-related occupations, waste and wastewater management, healthcare, arable farming and occupations that involve travelling for work and contact with travellers, such as for example in customs work. The result of this research is summarised in five articles describing the specific risks from biological agents for workers in these occupations and examples of prevention measures and programmes, as well as specific vulnerable groups in these sectors (EU-OSHA, 2019a-f). Three of these five groups of occupations, i.e. animal-related occupations, waste treatment and healthcare were discussed in the focus groups, which

explored current and emerging workplace risks and the policies and initiatives in place to prevent these risks.

The association between occupation and diseases resulting from biological agents (excluding allergens) is clear among healthcare workers at risk of blood-borne and other infections, and for occupations that involve the intentional or inadvertent handling of animals. For allergenic agents, the sectors and occupations that were identified as being at a clear occupational risk are the agricultural and fisheries sector, the food industry, the wood-working and metal industry, and occupations in waste management and wastewater treatment.

High-risk occupations

Regarding **animal-related occupations** (abattoir and slaughterhouse workers, agricultural workers (including animal farming), laboratory workers, veterinarians), animal farmers frequently mentioned and reported respiratory health effects.

Veterinarians may get infections through direct animal contact or bites by vectors (e.g. ticks, lice). Among abattoir and slaughterhouse workers, bird-related zoonoses, bacteria-related diseases and tick-borne diseases may occur more frequently. Smaller outbreaks of Q fever were also reported by stakeholders. Laboratory workers who handle insects or laboratory animals are particularly exposed to allergenic agents. Immediate onset of hypersensitivity reactions from exposure to laboratory animals' urine, hair, dander and/or saliva are possible.

Organic dust – which facilitates the spread of bacteria and viruses – was identified as a high priority risk and is mainly caused in these occupations by intensive breeding of animals and dust generated when feeding animals and cleaning. Exposure to organic dust could be reduced by raising awareness and providing guidance on how to avoid exposure and how to improve cleaning methods, correct storage and handling of feed and litter, and, if necessary, the of use personal protective equipment (PPE). Hygiene measures and the separation of work clothing from street clothing (black-white areas) can help prevent the spread of infections and organic dust to other areas of farms.

In **arable farming,** workers are exposed to a diverse range of biological agents due to their work with crops, and this can lead to various diseases. Tick-borne diseases, Crimean-Congo haemorrhagic fever (CCHF) and lung diseases are reported in this sector, and exposure to organic dust is frequent. Farmer's lung, caused by inhalation of microorganisms from products stored in conditions favourable for their growth, is likely the most common allergic condition among agricultural workers. Lyme disease is also predicted to be a significant health concern in the coming decades because of the spread of ticks due to changes in climatic conditions. Measures exist to prevent farmer's lung and other farmers' diseases related to the growth of moulds and bacteria, for example, dust-avoiding storage and processing methods of hay grains, animal feed or litter.

The waste and wastewater **management** sector comprises different subsectors: waste collection and handling of waste, recycling and composting, and wastewater treatment. Infections with HIV and hepatitis B may be caused by sharps injuries during handling and sorting of waste. Many experts stressed the need in this sector for vaccinating workers to prevent bloodborne diseases due to needlestick injuries. Adverse respiratory effects due to exposure to bioaerosols or organic dust are also frequently reported in this sector, in particular among waste handlers and these exposures may also cause irritation of the nose and an increase of immune system activity. The wide variety of risks during waste handling, composting and recycling makes it difficult to determine the best way to control risks due to biological agents. Possible measures against the risks in this sector are technical solutions such as improving ventilation or separating workers from waste entirely and better training and information for workers. The experts also stressed the need for clear regulations and the setting of maximum limit values to improve OSH prevention.

Allergenic agents are considered a clear risk in sewage and wastewater plants. A causal relationship between exposure to non-infectious airborne biohazards and the occurrence of gastrointestinal symptoms, fever, respiratory symptoms, skin disorders, eye irritation, headache, fatigue and nausea among the workers of sewage treatment plants was reported. Leptospirosis, an infectious disease that can pass from rats to humans when a minor skin injury is exposed to water or soil contaminated with animal urine, caused by *Leptospira* spp., has also been reported among wastewater and sewage workers.

Of all the sectors considered in this review, most information regarding work-related diseases due to exposure to biological agents was available for **the healthcare sector**. Health risks are most frequently reported in relation to accidents with sharps (mostly needlestick injuries), which may lead to viral infections. The primarily described diseases are influenza, tuberculosis, hepatitis and HIV. Policy measures in the healthcare sector are, for example, the implementation of safe needle systems and emphasis on continuous training and information for medical as well as non-medical staff (e.g. cleaning personnel) and temporary workers.

Surgical smoke([5]) is an issue that was mentioned in relation to the use of newer operating techniques, but not addressed by the experts who discussed prevention measures. Nevertheless, it should be mentioned that this sector is considered well-regulated because of the relatively high awareness of biological risks and its workers following the regulations. This primarily applies to nurses and doctors, whereas for cleaners and foreign workers there is still a lack of awareness.

Travelling is generally assumed to increase the geographical spread of diseases not commonly encountered in Europe. **Occupations that involve travelling or contact with travellers** were considered of concern because of changing patterns in travel and global trade, the emerging risks related to travel to and from endemic areas and the potential spread of diseases. Specifically, hepatitis E incidence is associated with travel to endemic areas. Moreover, the migration of immigrants/refugees to Europe may also introduce such diseases and this may put workers providing services to migrants at risk.

The types of workers at risk of contracting similar diseases to those of leisure and business travellers are transport staff and workers at borders (e.g. airline personnel, customs workers), global trade workers, workers in war zones, epidemic control (field) workers, epidemiologists, journalists and media

([5]) Surgical smoke plume is a dangerous by-product, a gaseous material generated from the use of lasers, electro-surgical pencils, ultrasonic devices, and other surgical energy-based devices. As these instruments cauterise vessels and destroy (vaporise) tissue, fluid, and blood, a gaseous material known as surgical smoke plume is created. It is estimated that approximately 95 % of all surgical procedures produce some degree of surgical plume.

professionals. The diseases associated with infection risks for these workers are avian flu, Q fever, dengue fever, Ebola/Marburg virus infection, tularaemia, legionellosis, measles, tuberculosis, yellow fever, SARS, cholera and meningitis.

Other occupations and sectors

Although the qualitative research mostly focused on the five prioritised sectors and groups of occupations, information on other sectors was also obtained, in particular from the literature review. There is a clear association between occupation and disease among forestry workers (tick-borne-related diseases), sex workers (sexually transmitted diseases), and workers maintaining air-conditioning systems, who are at risk of *Legionell*a infection. Childcare was mentioned as a risk, because children may be exposed to more biological agents and transmit the biological agents to workers through physical contact.

SMEs

Although hardly any information was retrieved regarding small and medium-sized enterprises (SMEs) in the literature survey, the experts and practitioners involved in this study agreed that the management of biological agents may be challenging for SMEs, given their lack of knowledge and awareness. Consequently, training and awareness-raising were recognised as particularly important in SMEs, of which there are many in, for instance, the agricultural sector (both arable farming and livestock farming). They are difficult to reach, and often have fewer (financial) means to implement control measures.

One way to reach SMEs could be the implementation of policy measures at the municipal level, which may create a more direct relationship between the local government and SME owners, resulting in more communication and awareness. It would also be beneficial to work through the sectoral organisations, who know best the specific conditions of the sector and provide very short, sector-specific information to SMEs. Italy has provided subsidies since 2010 for enterprises that want to improve their working conditions, including the control of risks due to biological agents. In Ireland, an online tool called 'BeSmart' (Business Electronic Safety Management and Risk assessment Tool) aims to help business owners/managers prepare a risk assessment and safety statements for the workplace. The tool highlights the main hazards in a sector and covers biological agents. In the Netherlands, Stigas([6]) provides a tool for entrepreneurs and workers in the agricultural sector.


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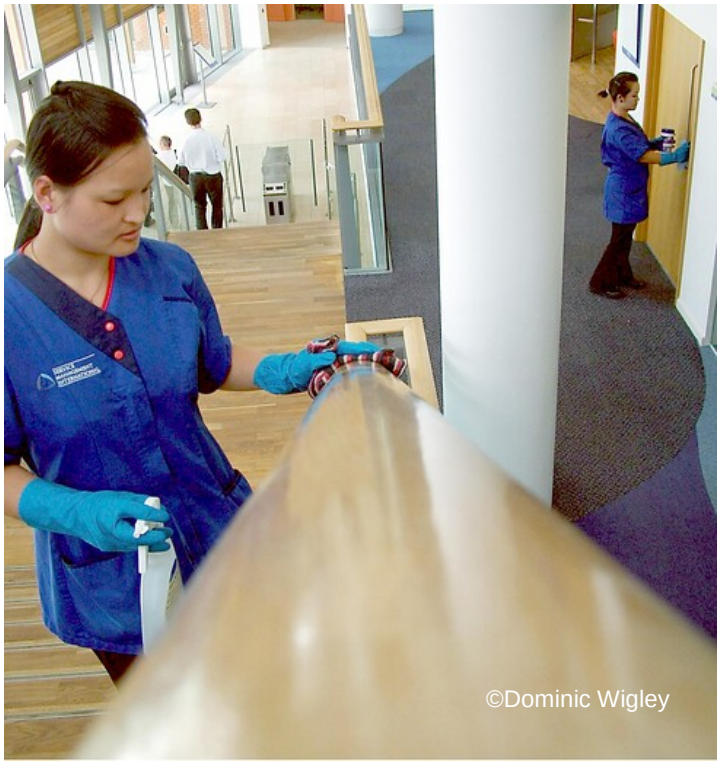
Another approach was chosen in Finland when setting up occupational health services for the agricultural sector that work as intermediaries for the prevention messages and are provided with specific technical knowledge for the sector. They provide consultancy to farms and at the same time perform health checks among workers at these farms.

Vulnerable groups

One of the objectives of this research was to identify vulnerable groups among the workers exposed to biological agents. Vulnerable groups across occupations include trainees and (young) workers in their first jobs (who may be at a higher risk than their more experienced colleagues), pregnant workers, elderly workers (being more susceptible to the effects of biological agents), the immunocompromised, people with chronic diseases, temporary workers, foreign/migrant workers, cleaners and maintenance workers and workers that have undergone chemotherapy. Legal

[6] Stigas is an independent knowledge institute that works for all agricultural and green sectors. Stigas stimulates employers, employees and the self-employed in the agricultural and green sectors to work healthily, safely and sustainably. Their services include: 1) legally required activities such as risk inventory, risk evaluation and preventive medical research, 2) information and training for machine safety, hygiene and healthy movements during work and 3) programmes for e.g. sustainable employability.

requirements are laid down in two EU directives covering pregnant and breastfeeding workers, and young workers, and the national requirements implementing these directives should be taken into account when setting preventive measures for those groups. However, the other vulnerable groups identified in this review should also be taken into account in workplace risk assessment and specific preventive and protective measures need to be set for them.



Vulnerable groups specific to a sector include young health workers working abroad or in resource-poor countries and temporary workers in agriculture and cleaning and maintenance workers are also considered to be at high risk in the waste treatment sector.

Some groups of workers may be more vulnerable to specific biological agents and these include those exposed to organic dust: pregnant women, people with pre-existing diseases, like lung diseases, allergies and asthma, people who suffer from diabetes (because of increased risk of infections) and people with (other) chronic diseases. These risks could be addressed by applying more stringent dust prevention measures and using protective equipment.

There is a need to improve training programmes for new workers in work sectors and occupational groups that are identified as being at a high risk of biological agent- or allergen-related diseases in this report. Awareness should be raised among employers about the needs of these groups and their obligation to protect them at work.

Emerging risks

One of the objectives of this review was to collect information on emerging risks related to biological agents' exposure at work, the related health problems and how these could be prevented. The validation of the information in the literature review and in the qualitative research with experts for this review is not straightforward, however. Information on the prevalence or incidence of exposure to biological agents and the associated diseases is scarce.

The concept of emerging risks covers newly created or newly identified risks, growing risks or risks that are becoming more widely known or established. The definition of emerging risk was first included in an EU-OSHA forecast of emerging biological risks (EU-OSHA, 2007).

An ‘emerging OSH risk’ is often defined as any occupational risk that is both new and increasing.

In terms of biological agents in Europe, new bacteria developed through bioengineering and increased exposure to bacteria and fungi due to the increased collection and separation of organic waste were considered significant emerging risks. The experts involved in this review warned that the expected increase in green jobs in the future may result in an increased prevalence of sensitisation to biomass-related allergens.

Furthermore, due to the huge migration flows of recent years, the risk of transmission of biological agents from the Middle East and Africa to Europe is considered an important factor. Despite the greatly increased movement among populations from very diverse regions (including Asia, Middle East, Africa) to the European region, research on the transmission of biological agent-related diseases from populations outside the region was limited to only one publication, although without occupational context, indicating and important research and monitoring gap.

Climate change is also considered a significant parameter with respect to newly created risks in that it influences the geographical distribution of the vectors (ticks, mosquitoes) of biological agents, thereby facilitating the spread of diseases that are new to a region. Risks linked to exposure to biological agents at work emerging in Europe, as detected by the literature review, are for example, Rift Valley fever, yellow fever, malaria, dengue, chikungunya, and Crimean Congo haemorrhagic fever. The hepatitis E virus appears to be an emerging problem in several industrialised countries, where it is mostly associated with either travelling to a hepatitis E virus-endemic area, for example, airline personnel, or with contact with pigs (which are a major reservoir of the hepatitis E virus).

Indeed, the EU-OSHA expert forecast on emerging biological risks (EU-OSHA, 2007) indicated that livestock may act as a reservoir of biological agents, potentially resulting in global epidemics or zoonoses, covering diseases such as severe acute respiratory syndrome (SARS), avian influenza, the Ebola and Marburg viruses, cholera, dengue, measles, meningitis, yellow fever, Q-fever, legionellosis, tuberculosis, and tularaemia, all of which may be particularly relevant to animal-related workers (EU-OSHA, 2007). This was confirmed by the research in this review which identified a wide range of possible zoonoses. In addition, there may be a wider spread of these diseases due to either climate change, changes in the way the sectors are organised, for example for breeding and transport of animals, the travelling patterns or the economic changes and the goods and migration movements caused by globalisation of the economy. The recent Coronavirus epidemic is one example of such an impact. An

overview of the many diseases and biological agents causing them is provided in the literature review (EU-OSHA, 2019a).

For animal-related occupations, especially animal farming, the increasing industrialisation of activities was recognised as an issue due to the increase in size of industrialised farms and numbers of animals, facilitating the spread of diseases. Intensive breeding and technological changes in agriculture are also putting workers at risk of being exposed to organic dust. The increased resistance of microorganisms to antibiotics was another risk mentioned in the literature and tackled in several Member States; this development puts care professionals as well as workers in the agricultural sector at risk because of intensive breeding and widespread use of antibiotics. It was reported that the high number of animals kept in husbandry may lead to bacterial resistance to antibiotics.

Changing patterns in human behaviour, notably travel behaviour, are also considered a major player in emerging risks. The fact that vaccination programmes for diseases such as pertussis and malaria, which are most commonly associated with developing countries, now exist in EU states suggests that some countries (e.g. the United Kingdom, the Netherlands) recognise the importance of (work) travel in the distribution of diseases from the EU region.

Stakeholders had also mentioned a few issues in addition to those identified in the literature review, such as the resurgence of tuberculosis, linked, inter alia, to migration of people from outside the EU; the wider spread of vector-borne diseases and leptospirosis, linked to climate change; and the issue of new viruses. The Zika virus was one that has recently caused concern, and which was nonetheless not prominent in the literature search. In addition to these issues, experts and stakeholders highlighted the resurgence of common childhood diseases, the unpredictability of allergic reactions and the importance of addressing antibiotic resistance. GMOs and tetanus were two issues that were not identified in the literature survey and were not addressed by experts and workplace practitioners. Finally, re-emerging diseases were also identified, such as Q-fever, tuberculosis and influenza among occupations in agriculture and healthcare.

Monitoring systems

The systems for monitoring exposure to biological agents and/or the related diseases assessed in this review vary to a large extent among the five evaluated countries. They differ in terms of what is monitored, how frequently it is monitored and the level of detail in monitoring. Moreover, the information from monitoring systems is often not publicly accessible, and if the information is available it is often summarised, for example by class of biological agents, omitting the culprit biological agent(s) and making it difficult to identify the disease.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It is even more difficult to monitor disease when it is caused by a mixture of biological agents, for example farmers´ lung caused by organic dust. This limits the possibilities for a comparative analysis of work-related or recognised occupational diseases at the EU level. Ideally, to harmonise the different monitoring systems, it was suggested by the experts that information is made available to stakeholders as much as possible, with a standard set of key parameters that need to be monitored. It would help if the output from the systems in each country were published according to causative agents (exposures), industries/sectors, jobs/occupations, age, and gender. It was also recommended that English be used as the overall reporting language, and that the level of detail that should be reported is agreed on.

Underreporting

Furthermore, diseases in general, and thus also work-related diseases related to biological agents, are known to be underreported. Providing more guidance and training on, for instance, criteria for the recognition of specific diseases due to biological agents, may result in less underreporting. In combination with a harmonised structure of monitoring systems in European countries, a better overview of the occurrence of disease due to exposure to biological agents in the workplace, including emerging biological risks, could be generated. This would provide better information that could be used to target and prioritise preventive measures. It would also enable comparison between countries and between industries within countries. This in turn could result in more effective preventive or control strategies being implemented.

A missing link to prevention

Even with a suitable output, it is unclear to what extent the stakeholders use this information to target prevention. In general, the information is provided in annual reports, which are distributed among stakeholders such as ministries and the Labour Inspectorate. However, the information is not very precise and as the analysis of the data in this review shows, is not useful for a detailed assessment by disease, biological agents, allergen, sector, occupation, age or gender. As no information on the prevalence of diseases or exposures can be gathered, it is very difficult to identify those groups that are most exposed or rank and prioritise sectors or occupations or the causative agents for action and prevention.

Some systems do, however, collect information on follow-up action at the workplaces and this information can be very valuable where similar problems occur, in research or for the development of workplace guidance. Experts have highlighted the need to digest and communicate such information in a way that makes it accessible to the workplace level and suitable to the target groups. Such a function does seem to be fulfilled by some of the expert networks that exist, for instance those that are linked to a reporting system (for instance for specific zoonoses) or those linked to the alert and sentinel systems.

Limited coverage of sectors and occupations

Self-employed workers are often not included in the registration process. Some systems report limited coverage of specific sectors of the workforce (e.g. agriculture) or specific groups of workers, such as maintenance workers, who may not be covered either by legislation or by notification and recognition procedures. In the chapter on vulnerable workers a number of workers with potentially insufficient coverage were identified, for example temporary workers (for example migrant workers in agriculture or waste management), young workers or trainees, for instance when they engage in health systems abroad, or those who travel for work or are in contact with travellers or immigrants, for example. It is not sure whether diseases they contract in the course of their travelling or placements abroad are registered as work-related or occupational diseases. More effort is therefore needed to ensure the recognition of health problems affecting those groups, their work-relatedness and reporting of diseases to the monitoring systems and raise awareness among those who report these diseases.

Types of diseases that are recorded

Both **infectious and respiratory and allergic diseases** related to biological agent exposure were covered by the systems, despite the fact that the second group was not related to specific biological agents or even exposures. These diseases are multifactorial and biological agents, including specific ones, can be identified as one of the causes, but it is difficult to link the effect to one cause or one agent. Workers affected by these diseases are normally exposed to a mixture of biological agents (for example in organic dust) and a mixture of biological and chemical agents. This may challenge the principle behind the definition of recognised occupational diseases, which postulates the need for an occupational disease to be primarily caused by a specific agent that can be clearly identified. Nevertheless, some of the systems described in this review do allegedly include diseases aggravated by certain exposures, for instance to biological agents. The diseases registered under these categories also represent a high proportion of the diseases linked to biological agents. It may very well be that the guidance documents for the different countries and diseases provide more detail.

What also emerges from the analysis is that **zoonoses** are recorded to a varying extent, although their importance is recognised in literature and by the experts who contributed to this review. While zoonoses are differentiated in the compensation system (IIDB) in the UK, and are also included in the French sentinel system, this is not the case in the official statistics of occupational diseases in Germany for example, where they are presented under one category, although they represented about one quarter of the notified diseases in the latest statistics from 2018. Again, this makes it difficult to differentiate between occupations and causes of disease and to target prevention.

Detection of emerging risks

For the detection of new occupational health risks, instruments other than those used for monitoring known occupational diseases, may be needed. Information that is routinely collected as part of the public health system could possibly be used to this end and several complementary methods are considered necessary for the detection of emerging risks, such as epidemiological studies, health surveillance studies, and the evaluation of cases, ideally by an (international) team of experts. A warning system for emerging biological risks should be combined with an action plan aiming at a rapid response to minimise the risks due to these agents at the workplace. In France, for example, an alert system ensures warnings are exchanged to prevent the spread of emerging zoonotic diseases for which registration is not mandatory. A network of professionals from (occupational) health services in multidisciplinary teams can exchange information on alerts. The target groups are farmers, and foresters, workers in animal husbandry, environment professionals and workers at zoological parks. This measure can likely be transferred to other countries and this example could be followed for other diseases

The identification of new and/or emerging risks could be part of the regular monitoring system of occupational exposures and/or diseases and could be based on the evaluation of a case by of an (international) team of experts, for example, using their national experience, data mining and literature searches, such as in the French RNV3P system. Such an approach is proposed by the Modernet occWatch system([7]) that registers cases across countries. National alert and sentinel approaches are explored more in detail in another study commissioned by EU-OSHA that analysed more in depth such systems and provided recommendations in this respect (EU-OSHA, 2018b). Wider access to the background information available in these systems on exposures and conditions of exposure as well as the potential causes for any health problems would ensure that the systems can be adjusted and refined and ongoing training and retraining can be provided to reporters. Such a feedback mechanism does exist for a number of alert systems that are described in this review and the valuable contribution of these systems to the improvement of workplace monitoring should be more widely recognised. These systems (for example the RNV3P system or the SIGNAAL system developed in Belgium and the Netherlands) could help identify emerging disease as they also collect case information and include a thorough assessment.

A network of professionals from (occupational) health services who participate in multidisciplinary teams (veterinarians, general practitioners, occupational physicians) could be provided with support for the rapid exchange of information for prevention of zoonotic disease, for instance. Sectoral organisations could investigate in their own sectors and facilitate epidemiological studies. , Depending on the networks providing the information, whether occupational health centres as in the French approach or specialist networks such as dermatologists or pneumologists in the UK THOR networks, the specialist knowledge could be a valuable asset to progress in the recognition of diseases at the international level.

A more direct link between public health systems and OSH systems could enable the collection of valuable information that may be used to target the prevention of exposure to biological agents at the workplace. For instance, to combine experience of sentinel systems for infectious or chronic diseases from public health with knowledge of exposure patterns from occupational health, would support better identification of the work-related diseases, the causes, the context, help avoid underreporting, and

[7] OccWatch (https://occwatch.anses.fr/node/10) stands for "Occupational Diseases Watch". It is a Sentinel Clinical Watch System dedicated to the highlighting of newly occurring Occupational Diseases. OccWatch sentinel clinical system is powered by the French Agency for Food, Environmental and Occupational Health & Safety (ANSES), the operator of the French National Network for Work-related Diseases Vigilance and Prevention (RNV3P), which developed for several years a specific approach to handle new work-related diseases.

enable an assessment of the contribution of work to overall disease rates. Equally, the information from such registries, whether their purpose is the protection of animal health (in the case of zoonoses) or of public health (in case of registries that register certain infectious diseases, such as tuberculosis, for example), could be useful to recognise outbreaks of diseases and organise timely workplace prevention in the concerned sectors. The precondition for this would, however, be an exchange mechanism with occupational health authorities or expert networks.

General practitioners are sometimes involved in the registration of occupational diseases and could also register cases of occupational diseases that are not picked up by occupational physicians and other OSH professionals. However, some information would be needed to make such information useful for workplace purposes, for instance on the work history of the person in question. It could be supplemented by information from job-exposure matrices as proposed by some experts in the stakeholder workshop. The Finnish institute for occupational health FIOH has developed the FINJEM, the Finnish Job Exposure Matrix. Even when only a job title is known, the exposure of a worker can be estimated based on the exposures measured in large groups of workers with similar jobs. Exposures that are relevant for biological hazards in the FINJEM database are those to organic dusts (such as animal, flour, plant, softwood and hardwood dust) and to microbiological agents (mould spores and gram-negative bacteria of non-human origin). Other job-exposure matrices could be built on this model.

Monitoring of exposure

Little information is available on exposure to biological agents at the workplace. The exposures are not measured frequently, and as good quantitative data on exposure and the associated effects is missing, a very limited number of occupational exposure limits (OELs), mostly at a very general level and not related to a specific agent, and only a few systems for monitoring exposure exist. However, although quantification of exposure to biological agents is complex, several measurement and analytical methods for biological agents do exist. Further development of these methods is recommended to enable control or prevention of such exposures and this includes the availability of immunological tests. Exposure measurement methods should be developed for those diseases that are most frequently recorded and measurement for agents causing respiratory and skin diseases and important sectors identified in the review should be prioritised.

Availability of reliable, standardised exposure assessment methods and tools

With regard to the measurement of biological agents, instead of assessing the exposure levels of individual biological agents, one option would be to focus on more general markers of exposure to biological agents (such as organic dust or bioaerosols, endotoxins as a marker for Gram-negative bacteria, peptidoglycan or muramic acid as a marker of Gram-positive bacteria, glucans as a marker of fungi/moulds, and extracellular polysaccharide antigens of the *Aspergillus* and *Penicillium* species (EPS-Pen/Asp) as a more specific marker of fungal exposure). The availability of standardised measurement methods could stimulate exposure assessment, surveillance studies and epidemiological studies, which in turn may lead to the derivation of OELs.

For risks involving chemicals, radiation and vibration, several workplace risk assessment methods and tools exist. However, for biological agents it is difficult to obtain a complete overview of the risks because hardly any tools are available. Control banding could be considered, by means of, for instance, a qualitative assessment of biological risks at the workplace by using, for example, risk assessment tools in combination with options for control measures as a first step to reduce risks. In combination with available exposure data, this would be a step towards quantitative assessment. First examples of tools using such an approach are described in the report.

Further recommendations

Improving prevention at the workplace

The majority of the prevention policies identified in this review are aimed at preventing specific diseases among workers, such as respiratory diseases (e.g. asthma, farmer's lung), infectious diseases from bacteria or viruses (e.g. MRSA, Ebola, BSE, influenza, tuberculosis) and blood-borne infections (e.g. hepatitis B, HIV), and do not seem to cover the whole range of risks due to biological agents that were

identified through literature review and expert interviews. They focus mainly on situations with a clear risk of infection, and to a much lesser extent to biological risks arising from unintended exposures.

Overall, the policies and prevention measures described by the experts regarding all sectors were successful and most were transferrable across countries. Raising awareness of the topic among workers and employers as well as developing appropriate (technological) solutions was regarded as crucial. Reported success factors were effective OSH services, involvement of key intermediaries, cooperation between actors at the regional level, systematic health surveillance and systematic exposure assessment (for instance in a particular sector, or aimed at a particular group of workers).

Respecting the hierarchy of prevention measures:

Many of the preventive measures mentioned by the experts are measures applied to the individual (for example use of PPE or monitoring the use of PPE or vaccination) rather than linked to a general prevention approach. This approach does not follow the hierarchy of control measures prescribed by European legislation, which sets out that the risk should be eliminated altogether and only if it cannot, should collective organisational or technical measures be taken, and only as a last resort, individual measures such as PPE. It is particularly worrying that at the same time, the experts have highlighted a lack of access to appropriate PPE or lack of appropriate storage areas for such equipment that ensures its usability, as well as the fact that workers have to use the same PPE for long periods of time. They recommended the provision of additional information and training, and the opportunity for employers and workers to try PPE in a supervised way, to ensure a good fit with their practical needs.

An important conclusion from the findings is that awareness needs to be raised among employers and workers about the existing legal framework and the importance of applying collective rather than personal measures. Practices that are commonplace in the management of chemical risks should also be so in the approach to the prevention of workplace risks from biological agents.

This should include keeping the number of those exposed as low as possible, designing work processes so as to avoid or minimise exposure, developing technical measures at the design stage of work premises and work procedures, appropriate signage, plans to deal with accidental exposure, and measures for safe waste collection and handling and transport of biological agents, all measures that are included in the biological agents directive.

It should also be mentioned that Directive 2000/54/EC includes special control measures such as containment categories for laboratory work and industrial processes, and special attention is paid to healthcare and veterinary care facilities. The list of biological agents included in the directive also gives a separate indication in cases where the biological agents are likely to cause allergic or toxic reactions, where an effective vaccine is available, or where it is advisable to keep a list of exposed workers for more than 10 years. However, there are no details for the sectors and occupations with unintended exposure described in this review.

In addition to these prevention measures, hygiene measures are particularly important: this includes the separation of break and changing rooms, appropriate washing and toilet facilities, and the separation of work and other clothing.

Differentiation between ‘clean’ and ‘dirty’ areas (black-white areas) avoids the spread of contamination in sectors such as waste management, farming and health care, but issues linked to work clothing may also be relevant to other occupations such as border staff and transport workers. This is relatively simple to organise and can be applied in many of the sectors/occupations that are considered of concern with regard to risks due to biological agents. While these measures may be implemented in healthcare or the food industry for other reasons (patient or food safety), for instance, they are not in other sectors and should be implemented in sectors such as agriculture or waste management.

Vaccination and how to address low vaccination rates

Vaccination was a prevention measure that was mentioned many times by the experts involved in this review, for example regarding exposures in health care, waste management and animal-related professions and regarding the protection of armed forces. According to the biological agents directive, workers should be informed of the benefits and drawbacks of both vaccination and non-vaccination, and vaccination must be offered free of charge to workers, and the list of biological agents in the directive provides information on those agents for which vaccination is available. Quite a few of the sectors considered in this review would benefit from vaccinations being offered to workers and effectively

applied. However, vaccination rates are low and the reasons behind should be explored. There were also contrasting views as to whether or not there should be obligatory vaccinations, for example of healthcare workers.

Needlestick injury prevention

Needlestick injuries and the transmission of bloodborne viruses were widely addressed in the literature survey and by the OSH experts and practitioners, mostly, but not only, related to the healthcare sector, and for example the waste management sector. In addition to safe needle systems, national surveillance of accident types and the circumstances surrounding blood-related infections, prioritising the prevention of risks, was also proposed. The availability of safe needle systems is an issue and therefore the experts considered that interventions at the level of the providers are also needed.

Awareness needs to be raised at the management level of healthcare establishments, in particular those operating in mobile care and home care, and among those who purchase needles for private purposes of the risks of improper waste disposal, as well as those who dispatch the needles to users. Including pharmacies in the awareness-raising approach could be crucial.

Needlestick injuries are covered by EU directive 2010/32/EU on the prevention from sharp injuries in the hospital and healthcare sector([8]) and were addressed in an EU financed project, which made a number of recommendations in line with the ones stemming from this review. The reports from the project (HOSPEEM/EPSU, 2013) highlight non-permanently employed staff such as trainees, students or interns; newly employed workers; temporary agency staff; part-time staff only working at weekends or at night as groups at risk. In light of the figures mentioned in these reports and the finding that needlestick injuries are severely underreported in the healthcare sector as well as in other sectors, action at the level of enterprises and providers is urgently needed.

Covering unintended exposures

The Biological Agents Directive states that the obligations of employers still apply, even if the results of the workplace risk assessment show that an activity does not involve a deliberate intention to work with

[8] EU Directive 2010/32/EU on the prevention from sharps injuries in the hospital and healthcare sector implements the Framework Agreement on prevention from sharp injuries in the hospital and healthcare sector signed by the European social partners the European Hospital and Healthcare Employers' Association (HOSPEEM) and the European Federation of Public Service Unions (EPSU) on 17 July 2009, which is an annex to this directive.

or use a biological agent but may result in workers being exposed to a biological agent, as in the activities listed in Annex I to the directive:

1 work in food production plants;
2 work in agriculture;
3 work activities in which there is contact with animals and/or products of animal origin;
4 work in health care, including isolation and post-mortem units;
5 work in clinical, veterinary and diagnostic laboratories, excluding diagnostic microbiological laboratories;
6 work in refuse disposal plants;
7 work in sewage purification installations.

There may be other work activities that involve unintended exposure that are not included in this annex. Many of the occupations at risk identified in this review involve a considerable part of unintended exposures, as workers may be exposed to biological agents which originate from the work process or materials used in the work process, without the biological agent being deliberately used during work tasks (which could be the case, for instance, in a biotechnological process to produce enzymes, in vaccine production, in the production of antibiotics, in some research labs or in food production).

Rather than focusing on identifying each and every biological agent that may be present at the workplace, general prevention principles should be applied and some of them have already been mentioned above. This includes

- ventilation, including local exhaust ventilation where appropriate;
- dust- and aerosol-avoiding measures;
- avoiding contact with contaminated surfaces, animals and tools;
- regular cleaning and maintenance;
- closed systems or vehicles;
- the separation of dirty and clean areas, as well as
- appropriate PPE.

Furthermore, an approach that focuses on high-risk activities or processes within a sector, instead of a biological agent-based approach, may be more effective for the development and implementation of preventive measures. A process approach would especially facilitate the development of prevention measures for a specific process, e.g. sorting of waste. For multi-exposure risks for example, exposure to organic dust, solutions should be created on a higher than individual level by developing technological solutions that separate workers from the biological agents entirely.

Prevention measures regarding unintended use of biological agents could be built on those set out for intentional use of biological agents in other sectors, for example farms learning from approaches in the healthcare sector, for instance regarding antibiotic resistance. The report provides information on many measures, whether specific to sectors and occupations or general. However, it also identified a need for risk assessment tools that take into account the hierarchy of control measures as well as the specificities of biological agents (e.g. their ability to grow and spread, health effects, viability) and provides examples of successful guidance such as for example the technical rules for biological agents in Germany.

The combined risk approach was recommended in particular for unintended exposures, for example when developing preventive measures for risks such as organic dust (which contains a variety of moulds and bacteria). Control measures do not necessarily differ between different fields (e.g. biological agents and chemical agents), and the efficacy of these measures is assumed to be comparable. Considering prevention measures that are already in place to control other exposures (e.g. dust and chemical substances) may prove to be a good alternative approach to control biological risks.

The importance of allergens

The identification of allergens linked to biological agent exposure and their differentiation from chemicals agents is the most challenging issue identified in this review — although it is the most researched issue — as the exact cause of the allergy at the agent level cannot easily be identified. In the literature on allergenic agents, a differentiation between chemical agent and biological agent is not normally applied, although there are cases where a link between a substance originating from microorganisms and allergenic effects is elucidated. Some of the main causes are identified this report and include organic dust, moulds in buildings, flour dust, industrial enzymes, and specific bacteria occurring for example in waste management, wood processing and metalwork.

With regard to allergenic agents, the sectors and occupations with clear risks (in addition to the waste treatment sector) are the fisheries sector, the food industry, the textiles, wood-working and the metal industry. Water-miscible cutting coolants, for example, provide an environment that encourages the development of microorganisms, particularly bacteria and fungi, which can release sensitising cellular breakdown products and metabolites such as endotoxins and mycotoxins. Some OELs and technical guidance values for worker protection have been set in particular for some organic dusts, such as flour dust, or for endotoxins.

Although diseases related to allergens originating from biological agents exposure are among the most prevalent identified in the literature review as well as in the data extracted from monitoring systems, the exact causes are very rarely referred to in the statistics reports publicly available, with the exception of organic dust and farmers´ lung, and the proportions of diseases referred (generally grouped across all causes (e.g. hypersensitivity pneumonitis)) are merely estimated and cannot be retrieved from the official statistics. However, the statistics do refer to diseases exacerbated by exposure to biological agents and related substances, and therefore do, in some way, recognise the multifactorial nature of such diseases.

Data from health surveillance could also be used to identify causes and the groups of workers, occupations and sectors more at risk. Indeed, this is one of the elements of the successful approach by the Finnish occupational health services for the agricultural sector and it has resulted in improvement of the figures for farmer's lung and helps resolve problems in specific cases where those working on farms already show health problems. Employers could be reminded of the obligation set out in the biological agents directive that grants workers the right to health surveillance. Those arrangements shall be such that it is directly possible to implement individual and occupational hygiene measures. It could be more widely applied to identify and follow workplaces where health problems have occurred, identify the root causes and ensure that prevention measures are directl y implemented.

As a successful example of health surveillance, the experts suggested screening (future) workers for existing allergies or health problems, like the triage method for sensitisation (which in the future can lead to allergies and work-related asthma) for bakery workers in the Netherlands. The downside of screening is, however, the possible health effects on the worker when performing the tests involved, and that people may lose their job based on the outcome of these tests. It is conceivable to adapt workplaces instead of applying screening to select workers according to their sensitivity. Health surveillance should

be linked to preventive measures to prevent health outcomes due to biological agents rather than selection of workers who may resist in unhealthy conditions.

An example of the development of a (technical) solution in which a combination of organisational, technological and human factors is taken into account, was the implementation of far advanced compartmentation with strict cleaning and clothing regimes and good ventilation in the laboratory animal facility in which laboratory animal allergy was observed, where the same rules applied for both personnel as visitors. Similar approaches apply in other areas such as waste management and proper facilities need to be provided to workers to ensure procedures such as hand washing, decontamination of work clothing and disinfection. In quite a few areas where biological agents may occur, work clothing may be provided or needs to be separated from street clothing, owing to the infection and growth potential of biological agents. One area where this should be applied is for example the farming sector. It would also be important to respect these hygienic measures to help avoid the spread of zoonoses at source.

The German committees for biological agents and for hazardous substances have designed a joint technical rule on sensitisers that covers both biological and chemical agents. It provides details on workplace risk assessment, prevention measures and other obligations, such as for example the protection of vulnerable groups. A similar pragmatic approach could be taken in other countries, and experts from both areas could cooperate to design prevention measures for these diseases.

Furthermore, some databases, such as the MEGA database in Germany and the Finnish FIOH job-exposure matrix hold data on exposures to some allergenic factors, such as organic dust or textile fibres, and in highly exposed sectors such as waste management. The exchange of this data would facilitate the identification of groups at risk and help set targeted prevention measures.

The alert systems in place in some countries could also be valuable tools to identify potential causes of allergy linked to biological agent exposure. As the contribution of occupational exposures to allergic diseases is not easy to be defined, cooperation between occupational physicians and general health practitioners, as well as pneumologists and dermatologists, would be beneficial, to enhance prevention of these diseases.

Lastly, annex III to the biological agents Directive (list of classified biological agents) gives a separate indication in cases where the biological agents are likely to cause allergic or toxic reactions, for example through endotoxins. The exposures to endotoxins and the groups at risk from these exposures are another area that urgently needs more research and monitoring in order to design systematic prevention approaches.

Being prepared for outbreaks of serious diseases

The SARS epidemics including the recent Covid-19 pandemic and the effects of other serious zoonoses such as BSE have shown that urgent measures are needed to protect workers from the impact of a transmission of infectious diseases from animals to humans. What these epidemics have also shown is that a broad range of occupations could be concerned by such diseases, although at the onset this may not have been recognised. One issue mentioned by the experts in this context is pandemics and epidemics preparedness, and another is monitoring of these serious diseases. The respondents to the questionnaires in task 1 have mentioned several cases of smaller outbreaks, of for instance Q fever, at the local level. The German experts pointed out that healthcare workers in outpatient medical care are the first to be exposed to possible outbreaks because they treat infected patients and should therefore be included in preventive measures and receive training and information on how to deal with the risks. Considering the wide range of agents in question and the variety of sectors concerned, awareness-raising of these threats is urgently needed among all actors and the importance of the topic needs to be brought to the attention of policy makers. Emergency plans should be set up in enterprises for such incidences, but most of the time they are missing, whether it concerns an outbreak of a zoonosis in the farming sector or in the healthcare sector. This obligation, which is also a requirement on employers according to the biological agents Directive, should be made more operational and be brought to the attention of sectoral organisations together with the documentation and information requirements that come with it (recording exposed workers and informing them).

Experts explained that a number of monitoring systems that collect notifications of such diseases exist, mostly in the area of public health, but the information was not centralised and therefore not easily accessible; there is also a missing link to occupational safety and health. These systems cover specific infections, in particular zoonoses, and some coincide with priorities identified in the occupational field, such as the increase in tuberculosis infections and tropical diseases, or the increasing number of outbreaks of legionellosis. Some of these systems were installed in the public health field to improve prevention for groups of workers that are not well covered by occupational disease registration systems. This is the case for systems that record cases of brucellosis, for example, which are relevant for agriculture, a sector with a high proportion of self-employed and family workers. If warning system such as epidemics warning and monitoring (for instance the EuroFlu Net approach mentioned by the French experts or obligatory reporting schemes for certain zoonotic or infectious diseases) are not in place and do not link up with OSH institutions, workplaces and sectors are very likely to be deprived of means to react on time to outbreaks such as those of BSE, foot and mouth disease, avian flu, or the increase of nosocomial infections with multiresistant organisms. Such events are likely to arise again, and it needs to be ensured that the response includes OSH considerations beyond the mere provision of PPE as in the case of the Covid-19 epidemic. Contingency plans and approaches need to be coordinated with other ministries (health, migration or internal affairs, agriculture, etc.) and it is important that the protection of workers is recognised as a priority in these approaches.

Sector level

The workplace practitioners involved in the focus groups stressed the need to act at the sectoral level and increase awareness among employers and workers in the sectors covered by this research. Some sectors that are highly affected by biological exposure, such as the agricultural sector, have a high number of SMEs, and the working conditions are changing due to restructuring and increasing industrialisation. They are also an audience that is difficult to reach, and have high proportion of temporary and migrant workers that may be particularly vulnerable. Implementation of legislation would be improved by practical guidance for employers in plain language on how to read and use the provisions of the Directive. An example of elaboration at a practical level are the Technical Rules in Germany.

Experiences in a sector are sometimes transferable to other sectors and should be used accordingly. Cooperation with and between sectoral organisations could support the transfer of knowledge and guidance to the workplace level and help identify areas of concern, for example when conditions are changing in the sector. Several issues, such as the increase in multi-resistant microorganisms, the industrialisation of agriculture and environmental regulations that have an impact on waste management cycles, could be brought to the attention of policy-makers and workplace practitioners at an earlier stage.

Another suggestion from OSH experts was that the sectoral organisations could investigate specific issues, such as asthma in specific occupations, to support research and prevention, or support such research actively, by addressing their members and supporting data collection.

Moreover, it is recommended that companies and industry sectors receive guidance on how to set up surveillance programmes and how to design programmes to control and prevent exposure in specific work environments. The effectiveness of policy measures would be stimulated by effective information exchange between countries on policy measures and lessons learned.

Policies across sectors

Some biological risks were identified as an important issue in several sectors (e.g. organic dust, microorganisms causing multiple resistance to antibiotics, zoonotic agents). An approach similar to a lifecycle approach in environmental protection or a supply chain approach in chemicals legislation might deliver effective solutions to avoiding exposure or help set out preventive measures. Such an approach entails tracking the biological agents from their effects on human health back to the source from which they originated, which would enable action against the problem at the source and at all subsequent stages. For instance, to prevent needlestick injuries in waste-sorting centres, one measure could be to provide information early on to consumers, to prevent needles being disposed of in the general waste bin; this could be in the form of guidance for patients distributed at pharmacies on how to dispose of used needles in a safe way and providing specific needle-proof waste receptacles. Such an approach is more likely to take vulnerable groups into account, as they are more likely to be identified as part of

the chain of events, for instance cleaning workers in hospitals and maintenance workers in waste treatment, similarly to a supply chain approach. Other examples of supply chain approaches identified in this review include tackling the issue of resistance to antibiotics by reducing the use of antibiotics in both animal care and human care, and preventing further distribution of antibiotics in the environment (for instance via surface water) by means of waste(water) treatment.

National level

Biological agents are often not considered an OSH priority at the national level, which has resulted in a reactive rather than a proactive approach, compared with other dangerous substances in the workplace, and has limited resources for research, inspections and consultations. If biological agents were a higher priority on the national OSH policy agenda, more knowledge regarding this topic would be generated, which in turn would help employers to deal with this risk in the workplace more effectively.

At the national level, the visibility and approachability of experts and a proper dialogue and better collaboration between relevant stakeholders at several levels would facilitate influencing the agenda-setting process as well policy development and change. In several countries, there are expert networks with knowledge of exposure to biological agents at work that have different focuses and different statuses. The organisation of expert groups/meetings/platforms (at national and international level) would stimulate the sharing of knowledge, make it possible to respond more quickly in the case of an identified emerging risk, and would for instance facilitate reaching more harmonisation with regard to registration systems for relevant diseases and exposures to biological agents. On the one hand, the recognition of health problems could be improved and, as in the RNV3P network in France, alerts could be issued to prevention actors when a new risk or a new disease is recognised. On the other hand, these issues could be brought to the attention of policy-makers and those who develop standards, to ensure that they are addressed in regulations, guidance and the control of implementation by, for example, labour inspectors.

The experts also highlighted the need for a better link between public health and OSH actors at all levels. This is relevant for a better assessment of the diseases linked to exposure to biological agents, but also to the practical prevention and the identification of emerging risks. The recent COVID-19 epidemic is a very illustrative example. Other factors that were considered important for policies to be successful were media attention and public awareness.

European level

The experts and stakeholders involved in this review agreed that the EU directive on the protection of workers from biological agents at work provided an important framework that reflected the general prevention principles of the Framework Directive. However, they raised a number of important points that may be considered when revising the directive or designing guidance for its implementation.

At the European level, a wider definition of biological agents could be considered in Directive 2000/54/EC (Annex III); in addition to living (micro)organisms, substances or structures that originate from living or dead organisms, allergens and carriers of a variety of biological agents (such as bioaerosols or organic dust) could be included. The directive's definition of biological agents means that substances or structures that originate from living or dead organisms (such as exotoxins, endotoxins, glucans, mycotoxins and allergens) apparently fall outside its legislative purview, including the toxic, allergenic or irritative effects of these substances. This may have implications for how well these biological substances are considered in the national monitoring systems and health policies of Member States. These substances may fall in between the regulations for chemical and biological agents, and may thus be either structurally under-reported and/or not managed appropriately. It should be ensured that there is no gap in prevention of OSH risks between the chemical and biological agent-driven risks and the legislative areas are complementary and cover all risks, notably in sectors where awareness of the issues is low and prevention may be difficult to implement. Some of these sectors have been reflected upon in this review, for example, the agricultural sector, which is characterised by a wide range of tasks and procedures that may involve risks.

On the other hand, in the stakeholder workshop (EU-OSHA, 2018a) it was agreed that the scope and the definitions of the current biological agents in the Directive is useful, yet the list of biological agents

should be updated more frequently. Some Member states, such as Germany, for example, provide a list of biological agents of risk group 1. The harmonised categorisation and classification of these agents is also an important issue for monitoring exposure. The classification systems that are in use in France and Germany can serve as practical examples of harmonisation. Exchange of national information at the European level would facilitate the creation of an international list of biological agents or the regular update at the European level through technical amendments.

It was also recommended that the annexes to the directive be made context-specific for jobs and sectors, and a wider range of occupations and activities that are considered to be 'at risk' be taken into account more specifically in European legislation, to make sure that more are tackled by prevention measures in the relevant professions. In addition to the sectors in which working with biological agents is part of the primary process (industrial processes, laboratories and animal rooms), or in which workers come into contact with human or animal patients (healthcare and veterinary care facilities), the annexes could be adapted to refer better to specific jobs and sectors, especially those with mainly unintended exposures, such as composting, (waste water) recycling, agriculture (animal and arable farming), food processing, home/outpatient care, education, and occupations such as cleaning and maintenance work. The finding that a wider range of occupations is considered 'at risk' should be reflected in the Directive, to ensure that these are also included in the development and implementation of preventive measures in the relevant professions.

The inclusion of a reference to vulnerable groups could be considered, as they may vary depending on the sector and the biological agent. In the recent coronavirus epidemic, for instance, workers with respiratory disease or asthma and other workers with chronic health problems were identified as being at particular risk. These aspects may differ depending on the group considered and in the specific case of biological agents, issues such as immune status may also play a role.

Guidance for labour inspectors would also help support the implementation of the directive that may be quite challenging in sectors with unintended exposures. Some of these are fast-growing sectors, such as waste management and home care, and, at the same time, control and inspection may be a challenging task in these sectors. An exchange between those who implement the regulations in practice and an exchange with OSH services could be beneficial.

Finally, the development of a European (or even global) warning system would make it possible to respond more quickly and in a more structured way to emerging biological risks. Examples of alert systems exist at national and international level and some are described in this review. It could be an important step forward towards better prevention of risks for European workers.

1 Introduction

1.1 Background

Exposures to biological agents in the occupational environment are associated with a wide range of health effects, including infectious diseases, acute toxic effects, allergies and cancer. Although only a subset of all microorganisms (known as pathogens) cause diseases in humans, the health effects of biological agents have a major impact on public health. Worldwide, an estimated 320,000 workers die annually from work-related infectious diseases, 5,000 of them in the European Union (EU) (Hämälainen et al., 2007). More insight into and awareness of biological risks is therefore vital for a detailed evaluation of the health effects, including those of combined exposures. European Agency for Safety and Health at Work (EU-OSHA) research on emerging biological risks and national reviews (e.g. from Australia or Germany) have highlighted a lack of knowledge and awareness of exposures to biological agents and the related health problems, and the lack of a systematic approach to workplace prevention of these risk factors at work.

However, there is no systematic approach to estimating workplace exposure to biological agents or recognising the related health problems. A limited number of diseases related to biological agents — some of which are zoonoses — are recognised as occupational diseases. But there is little structured information on emerging issues in new professions such as waste management, wastewater management and composting, or other green jobs, or, for example, on emerging issues relating to the use of novel construction materials. New industrial activities have emerged in recent years in which exposure to bioaerosols can be abundant, for example biotechnology industries producing highly purified enzymes, and the detergent and food industries that make use of these enzymes; waste management and recycling technologies; and industrial animal breeding. Hazardous bioaerosols or new biological factors present in organic dusts that may induce work-related allergic and immunotoxic diseases among farmers and workers of the agricultural and wood industries have been identified.

Respiratory symptoms and lung function impairment are among the most studied effects. Workers suffering from specific diseases within this spectrum have been compensated in some EU Member States. Droplet aerosols, which are generated from water, oils, oil-water emulsions and other liquids in various work environments, may contain infectious agents (e.g. *Legionella* spp.) as well as allergic and/or toxic agents. Novel viruses and prions, emerging in different parts of the world, may pose a particular threat to the health and life of healthcare workers, food and agriculture workers, and veterinarians. Other important areas include the interaction of bioaerosols with non-biological agents, and other potential health effects, such as skin and neurological conditions and birth defects.

This is why EU-OSHA commissioned a review of specific work-related diseases due to biological agents, and this report summarises the results from this review.

Occupational exposure to biological agents can occur in two different ways:

1. It can occur through the intentional use of specific microorganisms in the primary process (e.g. laboratories, biotechnological industries).
2. It can occur as more or less accidental or unintended exposure resulting from processes that involve many different microorganisms or environments in which biological agents mostly occur naturally because of the growth conditions (e.g. composting, recycling, wastewater recycling, agriculture, food processing, health care, education). As a result, workers in a wide variety of occupations may be accidentally exposed to biological agents, although the risk of exposure is not always obvious. As some exposure situations are not part of the primary process and some of the health effects related to biological agents are rather unspecific, it is difficult to estimate how frequently exposure to biological agents in the workplace leads to disease. Not all occupational safety and health (OSH) professionals are familiar with biological agents; therefore, they may not recognise relevant exposure situations.

The research addresses these two types of exposure and includes exposures in professions in which there is unintended exposure and prevention is difficult, such as waste management and wastewater management in occupations that involve the handling of animals or food. Some of these occupations are among the fastest growing employment sectors in Europe, and OSH prevention should be improved.

1.2 Overall objectives of the review

Characterising work-related health effects caused by biological agents is often difficult, since the cause of the disease is not always directly related to the work environment. Therefore, it is assumed that these health effects are generally under-reported. Moreover, limitations in exposure assessment methodology and a lack of health-based (recommended) occupational exposure limits (OELs) for biological agents make it difficult to identify a particular biological agent as a risk factor (Health Council of the Netherlands, 2012). The latter, in particular, is assumed to hinder the implementation of targeted preventive measures. Furthermore, there is a general lack of knowledge and awareness of exposures to biological agents and the related health problems, and no systematic approach to workplace prevention of these risk factors (EU-OSHA, 2009a, 2009b). Therefore, more insight into and awareness of biological risks in the workplace are vital for a detailed evaluation of the health effects and for effectively controlling the risks related to biological agents.

The review therefore aims to:

- raise awareness of the issue of exposure to biological agents in exposed professions, especially those involving the unintended use of biological agents;
- increase information on health problems related to exposure to biological agents;
- support efforts to prioritise and structure the prevention of work-related health problems linked to biological agents;
- feed into European and national workshops on the topics covered.

Beneficiaries of the results of this project include:

- policy-makers at national and EU levels, including social partners;
- legislators;
- researchers;
- stakeholders in disease recognition and statistical data collection (e.g. national social security organisations);
- stakeholders at the enterprise level (e.g. health and safety managers, health and safety representatives, trade union representatives) and intermediaries involved in setting up company policies;
- sectoral organisations;
- policy-makers in other related areas, for example at the sectoral level, or in employment, public health and environmental policies.

The outcomes of this project are expected to:

- provide up-to-date information on the health problems and diseases linked to biological agents and raise awareness among beneficiaries;
- provide information on structured approaches to recognition and prevention that may support beneficiaries in designing policies and prevention measures, including practical advice aimed at the enterprise level;
- contribute to the sharing of information on these diseases to support the implementation of Directive 2000/54/EC([9]), especially in terms of unintended exposure of workers and biological risks in emerging sectors and occupations.

Furthermore, the results will serve as an input into EU-OSHA's efforts to increase knowledge and awareness of exposure to biological agents and the related health problems, and help design a systematic approach to the prevention of these risk factors in workplaces.

([9]) Directive 2000/54/EC of the European Parliament and of the Council of 18 September 2000 on the protection of workers from risks related to exposure to biological agents at work (seventh individual directive within the meaning of Article 16(1) of Directive 89/391/EEC).

1.3 Definitions — the scope of the review

Directive 2000/54/EC on the protection of workers from risks related to exposure to biological agents at work defines 'biological agents' as 'micro-organisms, including those which have been genetically modified, cell cultures and human endoparasites, which may be able to provoke any infection, allergy or toxicity'. It goes on to define 'micro-organism' as a 'microbiological entity, cellular or non-cellular, capable of replication or of transferring genetic material'.

This research project uses a wider definition of biological agents: biological agents are microorganisms and other carriers of plant or animal origin that can cause (sometimes severe) adverse health effects in workers after exposure, resulting in the following two groups:

1. living (micro)organisms (such as bacteria, viruses, fungi, yeasts and prions);
2. substances or structures that originate from living or dead organisms (such as exotoxins, endotoxins, glucans, mycotoxins and allergens).

Biological agents that are regarded as occupational hazards can be subdivided into two main groups, namely:

1. microorganisms that cause infectious diseases, for example zoonoses, which are contagious diseases that are transferred from animals to humans;
2. allergenic and/or toxic agents that form bioaerosols (e.g. bacteria, endotoxin, fungi) and cause diseases of the respiratory tract, conjunctiva and skin.

Directive 2000/54/EC classifies biological agents regarded as occupational hazards according to their level of risk of causing human disease, the severity of the disease, its potential to spread to the community, and the availability of effective prophylaxis or treatment. Based on this four-level categorisation:

- Risk Group 1 refers to biological agents that are unlikely to cause human disease.
- Risk Group 2 refers to biological agents that can cause human disease and may be hazardous to workers. However, these agents are unlikely to spread to the community, and effective prophylaxis or treatment is usually available.
- Risk Group 3 refers to biological agents that can cause severe human disease and present a serious hazard to workers; these agents may present a risk of spreading to the community, but effective prophylaxis or treatment is usually available.
- Risk Group 4 refers to biological agents that cause severe human disease and are a serious hazard to workers; these agents may present a high risk of spreading to the community, and usually no effective prophylaxis or treatment is available.

An annex to Directive 2000/54/EC proposes several prevention measures, which include special control measures such as containment categories for laboratory work and industrial processes. Special attention is paid to healthcare and veterinary care facilities. An indicative list of activities that entail exposure to biological agents is also included in an annex to the directive. Furthermore, the directive describes the minimum requirements to be implemented in national legislation, which include requirements to notify authorities of selected activities and a requirement for employers to keep records of workers likely to be exposed to certain biological agents (including information on exposure and health surveillance). Some EU Member States have introduced more detailed codes of practice and guidelines for the safe handling of biological agents, including guidelines for particular sectors and occupations.

1.4 Overall project outline

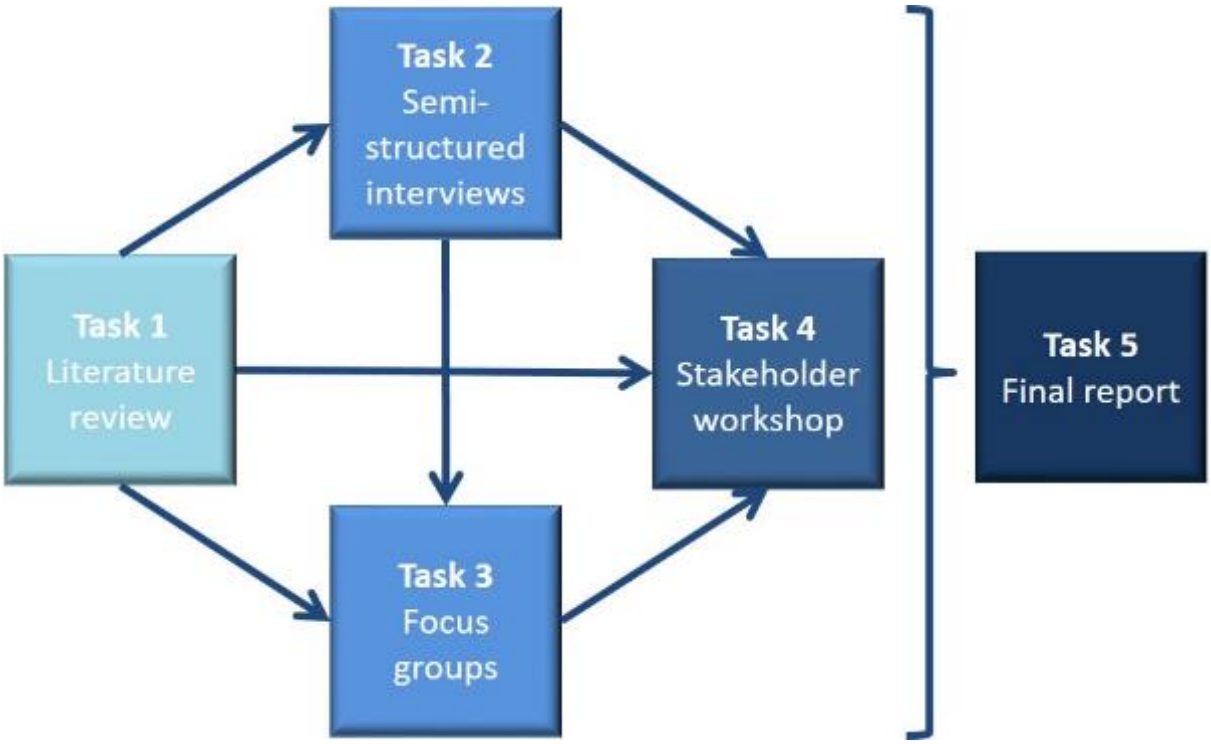
The project as a whole was divided into five main tasks, which were meant to build on one another (see Figure 1):

1. desk research, which consisted of a literature review on specific work-related diseases due to biological agents, an expert survey and an extraction of data from a selection of monitoring systems from countries with a reputable knowledge of the matter — these results are summarised in a report published by EU-OSHA in 2019 (EU-OSHA, 2019a);

2. the view on policy — semi-structured interviews with experts in five countries;
3. focus groups (semi-structured) with intermediaries in five countries;
4. a stakeholder workshop to discuss the results and overall draft conclusions;
5. final report, including analysis and policy options.

Figure 1 summarises the above tasks and how they relate to each other.

Figure 1: Overview of EU-OSHA-commissioned project on work-related health effects of biological agents and how the above tasks relate to each other



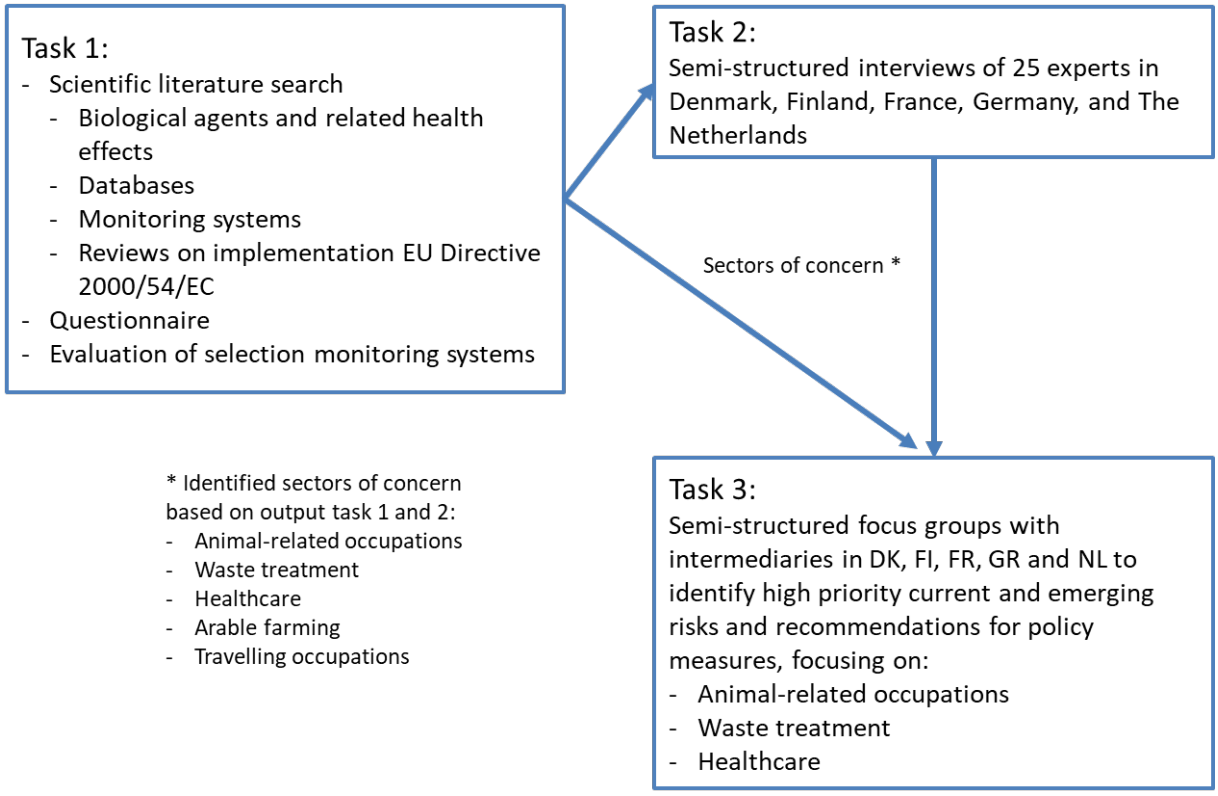
1.5 Objective of the report

The specific objective of task 5 is to provide a consolidated report of the findings of all parts of this project and proposals for policy options, linking the findings of tasks 1 to 4. Therefore, this report (task 5) presents the results from the literature review on specific work-related diseases due to biological agents (task 1), the expert view on policy, based on interviews (task 2), the experiences of intermediaries, based on focus group sessions (task 3) and the conclusions of the stakeholder workshop (task 4).

2 Methodological design of the project

Figure 2 presents a summary of the methodology applied in tasks 1, 2 and 3 of the project. It also indicates how the output of the first two tasks resulted in a selection of sectors being addressed in the focus group sessions (task 3). More details are given in the paragraphs below.

Figure 2: Overview of methodology applied in tasks 1-3, and selection of sectors based on the output of these tasks



2.1 Literature review on specific work-related diseases due to biological agents

The aim of the desktop research was to identify and summarise existing reviews of biological agents and adverse health outcomes, and studies on monitoring systems, databases and the EU directive related to biological agents.

The specific objectives of task 1 were to:

- review existing information on health problems related to exposure to biological agents, paying particular attention to vulnerable workers and covering infectious agents, airborne aerosols and allergenic factors in order to provide an overview of the work-related health effects and diseases linked to exposure to biological agents at work, as well as an overview of biological agents (including those that are less well known), and to identify emerging issues;
- identify emerging exposures to biological agents in new professions and new industrial activities;
- provide a structured overview and typology of the work-related health effects and diseases linked to exposure to biological agents at work;
- provide an overview and typology of biological agents, paying particular attention to those that are less well known;

- provide an overview of recognised and compensated occupational diseases linked to exposure to biological agents in Europe;
- identify monitoring systems that record work-related diseases linked to biological agents and/or exposure to biological agents, analyse a selection of them and describe their limitations;
- identify databases that provide systematic information on biological agents and risks to workers, and identify and explore existing EU or national datasets that contain information on work-related diseases linked to biological agents and/or exposure to biological agents;
- identify major reviews related to the implementation of Directive 2000/54/EC on the protection of workers from risks related to occupational exposure to biological agents in the EU;
- identify gaps in data/knowledge to feed, for example, into the development of exposure monitoring tools such as job-exposure matrices or exposure databases and disease registers.

To be able to fulfil these objectives, task 1 involved the following sub-tasks: (1) a scientific literature review, (2) a questionnaire survey and (3) an evaluation of selected monitoring systems (mainly identified on the basis of the output of the questionnaire and the subsequent integration of the results of these sub-tasks).

The scientific literature review focused on the identification and evaluation of reviews on the relation between biological agents and adverse health outcomes, published in either scientific literature or grey literature, by means of a transparent and reproducible literature search in the databases of Medline (through PubMed), Embase (through Scopus), OSH-Update (containing documents from the US National Institute for Occupational Safety and Health — NIOSH — International Labour Organization-based CISDOC, European Survey of Enterprises on New and Emerging Risks and Health and Safety Executive — HSE) and OpenGrey (containing European grey literature). This literature search was restricted to the period from 2010 onwards and reviews written in English, Danish, Dutch, French, or German. To perform this literature search, concepts were defined and combined to gather information on biological agents and/or related health effects, monitoring systems, databases and the EU directive (see Annex 1). In addition, the EU-OSHA, Organisation for Economic Co-operation and Development (OECD) and Eurostat websites were searched for relevant information.

A questionnaire was also developed, based on the outcomes of the scientific literature search (see Annex 2). The main aim of the questionnaire was to identify the existing systems that record work-related diseases linked to exposure to biological agents and gather information about each of them. In addition, respondents were asked if they were familiar with initiatives, campaigns, case studies, reports or studies on the subject, and what they regarded as the most relevant emerging biological risks (in terms of exposure and health effects); the questionnaire was also intended to gather information on cases/outbreaks of disease due to biological agents. For most of the questions, the number of examples the respondents could provide was limited to a maximum of three. They were asked to state which examples they considered to be the most important. The questionnaire was distributed among members of the EU-OSHA's network of focal points, the European Foundation for the Improvement of Living and Working Conditions' (Eurofound's) European Observatory of Working Life (EurWORK) ([10]), the Partnership for European Research in Occupational Safety and Health (PEROSH) ([11]) and Modernet (Monitoring trends in occupational diseases and tracing new and emerging risks in a network) ([12]). As the questionnaire was distributed among non-selected experts operating within various networks, the responses were not intended to provide a representative overview of, for instance, the systems in place

([10]) EurWORK gathers all Eurofound's resources on working conditions and industrial relations, and is supported by a network of European correspondents across all EU Member States and Norway. Eurofound runs two regular surveys on working life issues — the European Working Conditions Survey (EWCS) and the European Company Survey (ECS) — which are another major resource for the observatory.

([11]) PEROSH partners aim to coordinate and cooperate on European research and development efforts in OSH. The network comprises 13 OSH institutes, all of which play key roles in their national affiliations to governments/authorities and health and accident insurance systems.

([12]) Modernet was founded in 2008 as a collaboration between academic centres investigating occupational disease and work-related ill health incidence in a few EU Member States. Between 2010 and 2014, the network grew to include 12 more European countries and one institute from Australia.

in Europe. As in most cases only a few respondents per country filled in the questionnaire, with generally variable backgrounds and variable levels of experience in the subject, the responses gathered are considered only indicative.

From the national monitoring systems for biological agents and their related diseases identified from the results of the questionnaire survey, systems were selected for a more detailed evaluation, to see, for example, which data could be extracted, to assess whether or not such information is systematically collected to help target prevention towards the most relevant issues and emerging risks. Systems operated in Denmark, Finland, France, Germany, the Netherlands and the United Kingdom were evaluated. The focus was on generating an overview of reported exposures to biological agents and an overview of reported diseases due to exposure to biological agents; assessing the way in which the information generated by these systems is used, with a specific focus on whether or not it is used to target prevention (and, if so, in what way); identifying the limitations and/or benefits of these systems; and identifying the needs and potential for the successful implementation of such systems with regard to job-exposure matrices, exposure databases and disease registers. More details of the methodology applied in task 1 can be obtained from EU-OSHA's report on this task (EU-OSHA, 2019a) and from Annex 1 to this report.

2.2 View on policy: semi-structured interviews with experts

Task 2 involved interviews with experts to provide information on examples of policies regarding work-related diseases due to biological agents, their success factors and obstacles, and their transferability. The project team selected 25 people involved in policy, research and/or practice from five EU Member States (i.e. Denmark, Finland, France, Germany and the Netherlands), taking into account the broad types of national context, to gather an in-depth view of the policies in place in different European countries with regard to work-related diseases due to biological agents.

Tasks 1 and 2 identified the following five high-risk sectors:

1) animal-related occupations;
2) waste and wastewater treatment;
3) health care;
4) arable farming;
5) occupations that involve travelling or contact with travellers.

The focus of task 2, in addition to the literature review conducted in task 1, was to obtain more details on specific issues from an individual perspective, such as existing information on OSH policies targeting health problems related to exposure to biological agents.

The interviews were semi-structured and conducted either online using Skype or face to face. In total, 25 experts involved in existing policies on work-related diseases due to biological agents from the five EU Member States — five per country — participated in these interviews. The interviews were organised in each of the countries by the project partners (the Dutch Organisation for Applied Scientific Research, TNO; the German Federal Institute for Occupational Safety and Health, BAuA; the French Agency for Food, Environmental and Occupational Health and Safety — l'Agence nationale de securité sanitaire de l'alimentation, de l'environnement et du travail, ANSES; the Finnish Institute of Occupational Health, FIOH; and Aarhus University in Denmark) and run in the native languages of the experts selected. Based on the outcomes of the literature review, an interview schedule was developed. For instance, information on initiatives, campaigns or strategies related to the topic, as indicated by the respondents to the questionnaire (Part 3 of the questionnaire — see Annex 2), were considered. This interview schedule was used to introduce the participants to the different subject areas specified in advance, but other areas that arose spontaneously were also followed up on and probed. More details of the methodology applied in these semi-structured interviews are given in Annex 3.

The following areas were covered in each interview:

- the work and work-related background of the participant with regard to dealing with biological agents at work;

- the experience of the participant in existing sectoral policy measures to prevent and protect workers from the risk of adverse health effects caused by biological agents at work;
- the participant's view on existing policy at a national level to prevent and protect workers from adverse health effects caused by biological agents at work (attention was also paid to unintended exposures and emerging risks);
- the mechanisms for influencing policy and existing knowledge gaps.

The interviews further addressed the facilitating and hindering factors of (the implementation of) existing policies/policy measures and their transferability.

2.3 Focus groups of intermediaries

Task 3 aimed to learn from the experience of intermediaries (OSH service providers, labour inspectors, safety technicians, occupational health services, trade union representatives, etc.). The specific objectives of the focus group sessions in task 3 were to:

- identify high priority issues/risks due to biological agents that call for workplace measures/policy;
- identify new and/or emerging risks due to biological agents in terms of policy and prevention.

Denmark, Finland, France, Germany and the Netherlands were chosen as the focus group countries, as they are known to have reputable knowledge and infrastructure to deal with exposure to biological agents. Based on the results of task 1 and task 2 and the feedback from project partners in the different countries with regard to which of the five high-risk sectors were considered to be the most relevant, it was decided that the following sectors/occupations would be the main focus of task 3:

- animal-related occupations (animal breeders/carers/handlers, agricultural workers, veterinarians, abattoir workers, slaughterhouse workers, laboratory personnel, zoo personnel);
- waste treatment (waste collectors, waste composting workers, waste handlers);
- healthcare (healthcare providers and (para)medical professionals).

The focus groups were coordinated by TNO, organised in each of the countries by the project partners (TNO in the Netherlands, BAuA in Germany, ANSES in France, FIOH in Finland and Aarhus University in Denmark) and run with appropriate OSH intermediaries (OSH service providers, labour inspectors, safety technicians, occupational health services, trade union representatives, etc.) in their native languages. One focus group session was arranged in each country.

Based on the objectives of the task, a discussion guide had been developed by TNO, which included detailed and uniform instructions for the moderators and the second interviewers. Details of the methodology applied during these (semi-structured) focus group sessions are given in Annex 4. The topics discussed during the focus group sessions were:

1. the identification and prioritisation of current risks with regard to work-related diseases due to biological agents if there is a need for additional action/policy measures;
2. recommendations for policy measures for current risks;
3. the prioritisation of emerging risks;
4. recommendations for policy measures for emerging risks.

The discussions led to the identification of high-priority issues and emerging risks due to biological agents, and recommendations for policy measures and preventive measures to be taken to reduce the risk of exposure and related health effects.

2.4 Stakeholder workshop

The goal of the stakeholder workshop was to inform stakeholders of the (intermediate) main findings of the project and enable a discussion (on a policy level) with relevant experts and stakeholders on what can be done at both the European and the national level to (better) control the risks associated with exposure to biological agents in the workplace. In total, 37 people attended the workshop (from Austria, Belgium, Bulgaria, Croatia, Denmark, Finland, Germany, Hungary, Iceland, Ireland, Italy, Latvia,

Lithuania, Luxembourg, the Netherlands, Norway, Portugal, Romania, Slovenia and the United Kingdom). The group consisted of national experts with a good knowledge of exposure to biological agents in the workplace, the policies in place for workplace prevention, and the development and implementation of policies at the national level that were nominated by the Agency's national focal points. A representative of the European Commission and a team of researchers who prepared, led and summarised presentations and discussions also participated. During the workshop, TNO representatives presented the (intermediate) main findings (including emerging risks, monitoring systems and options for policy measures) of the project. Additional presentations were given during the workshop before the discussion: a representative of the European Commission gave a presentation on the results of an evaluation of the EU OSH *acquis* and proposals for amending the current directive on biological agents; the vice-chair of the German Committee for Biological Agents (Ausschuss für Biologische Arbeitsstoffe — ABAS) presented Germany's national system for the prevention of risks from biological agents, and the role of ABAS and its cooperation with other bodies; a representative from ANSES presented the French National Network for Monitoring and Prevention of Occupational Diseases (Le Réseau national de vigilance et de prévention des pathologies professionnelles, RNV3P) (including diseases caused by biological agents); and a representative from FIOH presented FIOH's activities in implementing OSH in the agricultural sector.

The presentation sessions were followed by group discussions. During these discussions, participants attended four rounds of discussions on four different topics and moved on to a different group discussion every 20 minutes. The discussions were supervised by members of the project team who were experts in the topic (chairpersons), and the minutes were recorded by designated member of the group. The participants had received the questions to be discussed and a draft version of the current report beforehand. The topics discussed were (1) monitoring diseases due to biological agents and exposures to biological agents, to discuss the (country-specific) challenges in monitoring disease, diseases that had not yet been addressed in the review or presentation sessions, the lack of exposure data and the systemic monitoring of disease; (2) the policies and practices in place to manage and control exposures to biological agents in the workplace, to look at country-specific initiatives and measures, as well as possible methods for developing systemic prevention, and the potential hindering and facilitating factors of the implementation of policies and practices; (3) specific sectors and groups, to obtain information on relevant occupations and sectors, in addition to the high-risk sectors that had already been identified, identify vulnerable groups that had not been addressed by the research and the workshop presentations, and identify issues related to small and medium-sized enterprises (SMEs); (4) the EU directive on biological agents, to discuss the definition and the classification of biological agents in the directive, and the sectors that are insufficiently covered by legislation. In addition, all group discussions covered the need for cooperation between countries and possible actions to be taken at the EU/international level. The group discussions were followed by a plenary discussion, during which the results of the different discussion groups were summarised. An online summary of the seminar and the presentations have been published on the EU-OSHA website (EU-OSHA, 2018a). The results of the group discussions and the plenary discussion and the additional information given in the presentations have been integrated into this final report.

3 Outcomes of the project

This chapter presents the outcomes of this project as a whole, organised according to themes, such as sectors and occupations of concern, vulnerable worker groups, emerging risks and findings regarding monitoring systems. The outcomes of the scientific literature search, the questionnaire survey and the evaluation of the selected monitoring systems (task 1), the interviews (task 2), the focus group sessions (task 3) and the stakeholder workshop (task 4) have been combined.

3.1 Sectors of concern in terms of exposure to biological agents and related health effects

On the basis of the outcomes of the literature search (task 1) and the areas that the interviewees indicated as emerging risks requiring awareness-raising (task 2), five groups of occupations and sectors of concern were identified, and the issues related to these occupations were investigated in more depth in the research:

1. animal-related occupations (i.e. animal breeders/carers/handlers, abattoir workers, slaughterhouse workers, veterinarians, laboratory workers);
2. arable farming;
3. health care;
4. waste and wastewater treatment and waste handling;
5. occupations involving travelling and contact with travellers.

Below, the risk and route of exposure to biological agents, the type of biological agents that cause health problems, and the risk and presence of disease in these occupations are briefly described, and, if available, the differences per country or area are highlighted. More details on the outcomes of the scientific literature review can be found in the report on task 1 (EU-OSHA, 2019a). As described in Section 2.3, for three of the five sectors of concern (animal-related occupations, waste treatment and health care), current and emerging biological risks were prioritised in a discussion with practitioners, and the experts gave recommendations for policy measures during these focus group sessions. For each of these sectors, the policy measures discussed during the interviews (task 2) and the experiences and views of the intermediaries discussed during the focus group sessions (task 3) are presented. Finally, the additional information obtained during the workshop (task 4) is also included and, when needed, discussed and contrasted with the research from tasks 1-3.

The Biological Agents Directive was recently amended following an evaluation of the OSH *acquis*, and Annex 1, which lists important sectors, was amended to include:

- work in food production plants;
- work in agriculture;
- work activities in which there is contact with animals and/or products of animal origin;
- work in health care, including isolation and post-mortem units;
- work in clinical, veterinary and diagnostic laboratories, excluding diagnostic microbiological laboratories;
- work in refuse disposal plants;
- work in sewage purification installations.

These activities are likely to involve a risk of exposure to biological agents; the activity itself does not necessarily involve a deliberate intention to work with or use biological agents but may result in them being exposed to biological agents. All of these activities are covered in the research summarised in this report, and many of the occupations were covered by the qualitative research.

Policy measures to promote the application of OSH regulations in agriculture (and health care) and support the prevention of serious infectious diseases (e.g. hepatitis; Ebola virus disease — Ebola; HIV infection; tuberculosis; particularly those classified in Risk Groups 3 and 4 in the EU directive) are also outlined below.

3.1.1 Animal-related occupations

Animal-related occupations comprise abattoir and slaughterhouse workers, animal breeders/carers/handlers, veterinarians and laboratory workers. An extensive table of biological agents (including bacteria, fungi, parasites and viruses) that this group of workers may be exposed to and the related health effects is provided in the literature review (EU-OSHA, 2019a) and in an article that summarises the exposures and related health problems (EU-OSHA, 2019b).

Abattoir and slaughterhouse workers

Abattoir workers' exposure to microorganisms is primarily caused by direct contact with infected animals, their body fluids or their organs.

The risk of infection among abattoir workers identified during the scientific literature search is not limited to those caused by bacteria (e.g. *Leptospira, Brucella*, *Coxiella burnetii* and bovine tubercle bacilli); these workers are also at risk of infection from a wide range of viruses, fungi and parasites. Bird-related zoonoses and the bacteria-related diseases among abattoir workers (e.g. from poultry) are ornithosis, salmonellosis, campylobacteriosis, yersiniosis, colibacteriosis, erysipeloid, tuberculosis and listeriosis. Virus-related diseases identified in the scientific literature search were West Nile virus infection and Newcastle disease. In slaughterhouse work, workers are also at risk of avian flu and influenza-like illnesses caused by the louping-ill virus, hepatitis B (human reservoir) and E. Fungal infection, which may result in histoplasmosis and cryptococcosis, whereas vector-related diseases are, for example, Lyme disease, Q fever and tick-borne encephalitis. Tick-borne diseases are of concern in this occupation, and workers can be infected via livestock blood and the body fluids and tissues of infected animals. Crimean-Congo haemorrhagic fever, a vector-borne disease transmitted by *Hyalomma* ticks, is endemic among slaughterhouse workers and agricultural workers in Africa, the Balkans, the Middle East and Asia. Its occurrence in Europe — notably in Spain and Portugal — has been confirmed by the presence of the *Hyalomma* tick in these countries, together with virological or serological evidence.

During the interviews (task 2; see Annex 5, Table 9 and Table 10), the experts identified several policy measures for the protection of abattoir and slaughterhouse workers. French experts, for example, reported a successful initiative for the prevention of bovine spongiform encephalopathy (BSE) among workers in the meat industry, such as slaughterhouse workers, including training on what is known about BSE and an information pamphlet. One of its success factors was the collaboration with regional

prevention stakeholders (CARSAT ([13]) engineers), who ensure direct contact with target groups. Another success factor was that all relevant organisations and ministries endorsed the documents by including their logo on them, a guarantee of quality and support. A Dutch initiative was aimed at slaughterhouse workers and focused on preventing respiratory problems through exposure to, for example, endotoxins. The measures included alternative techniques for cutting meat, and additional disinfection procedures (hygiene) for the slaughtering process. However, according to the Dutch experts, support from authorities was lacking, which made the initiative less successful.

Veterinarians

Veterinarians are known to be at risk of infection from a wide range of bacterial, viral, fungal or vector-related microorganisms. The risk of infection in this sector is considerable because veterinarians are frequently exposed to diseased animals. Infection may occur as a result of bites, scratches or other direct animal contact, or bites by vectors. Such infections may arise from methicillin-resistant *Staphylococcus aureus* (MRSA), (swine/avian) influenza virus, *Brucella* spp.*, Bartonella hanselae, Campylobacter* spp.*, Chlamyodphila psitacci, Clostridium tetani, Coxiella burnettii, Pasteurella multocida, Salmonella* spp., *Toxoplasma gondii*, and many other bacteria, viruses, fungi or vectors. It should be noted that one study reported an increased colonisation of MRSA but did not indicate any increased illness among veterinarians (Doyle et al, 2012). In India, zoonotic diseases account for up to 30 % of overall occupational illness cases among zoo and wildlife veterinarians. Although the situation in India may be different and is not comparable to the European situation, worldwide breeding programmes mean that veterinarians in European zoos may also be exposed to exotic biological agents.

http://www.pixabay.com

([13]) The pension and occupational health insurance funds (caisses d'assurance retraite et de la santé au travail — CARSAT) are organisations of the general social security system of metropolitan France with regional jurisdiction. CARSAT took over from the regional health insurance funds (Cram) on 1 July 2010.

Veterinarians may also experience allergic reactions such as asthma and hypersensitivity pneumonitis due to exposure to faeces, saliva, urine, serum and lipocalin proteins from the dander of domestic animals.

Emerging risks

Increased risks are reported due to climate change because the geographical range of certain biological agents is expanding. This was reported of the agents causing Rift Valley fever, yellow fever, malaria, dengue fever and chikungunya. Emerging diseases were seen in central and eastern Europe among veterinarians, with cases of human dirofilariasis being noted as an emerging zoonosis and infections due to the fungus *Sporothrix schenckii* (inducing sporotrichosis) being reported as a new risk category (EU-OSHA, 2019a).

The experts did not mention any policies that specifically targeted veterinarians. However, as in the agricultural sector, a successful measure in France was mentioned, which involves veterinarians participating in multidisciplinary teams (including both experts on animal health and experts on human health) to ensure that warning signs of diseases are exchanged and to prevent the spread of emerging zoonotic diseases for which registration is not mandatory (e.g. psittacosis, Lyme disease, Q fever, endocarditis).

Laboratory work with animals

Laboratory workers may be at risk of infection from a wide range of infectious agents, depending on their area of work and the tasks they carry out. A number of biological agents that they are exposed to — some of them through zoonotic transmission — are mentioned in the literature survey (EU-OSHA, 2019a). More information on working in laboratories is provided in Section 3.1.2.

Allergies — a significant risk

According to experts in the Netherlands, allergens in laboratory work with animals are the biggest risk, and this is confirmed by the literature review. Extensive research has been done on allergenic agents among laboratory animal personnel (EU-OSHA, 2019a). Laboratory workers who handle insects or laboratory animals are exposed to several allergenic agents, which can result in the immediate onset of hypersensitivity reactions from exposure to laboratory animals' urine, hair, dander and/or saliva, and bird breeding has been associated with hypersensitivity pneumonitis. Among animal rehabilitation workers, roe deer have been reported as new causes of occupational asthma.

Rodent allergy affects between 11 % and 44 % of exposed laboratory personnel, and can cause both acute and chronic symptoms, including contact urticaria, hypersensitivity pneumonitis, asthma, and even anaphylaxis and hypersensitivity pneumonitis. The primary allergens are contained in the urine of laboratory animals, with lipocalin proteins considered to be the major allergen. Recent evidence suggests that lipocalins, such as Mus m 1 (prealbumin), which makes up more than half of urine-excreted proteins, could trigger immune responses. This is proposed as a new mechanism that could initiate laboratory animal allergy (Jones, 2015). Although it may be considered counterintuitive, being allergic to domestic cats or dogs does not imply that one will be allergic to rodents, and vice versa.

Laboratory work with insects (i.e. fruit flies, insect larvae, locusts) and insect breeding (i.e. grasshoppers, tubifex and locust) are associated with occupational asthma, allergic rhinoconjunctivitis, bronchial hyperreactivity and/or anaphylaxis. Prevalence of work-related allergic symptoms is reported among laboratory insect handlers (26-35 %), field workers (0-6 %), laboratory scientists (7-13 %) and administrators (0-7 %). Allergic reactions were associated with exposure to a wide range of insects (EU-OSHA, 2019a).

Vulnerable groups

Young workers are particularly susceptible: in a study evaluating work-related respiratory allergies among young workers, including laboratory animal personnel, Moscato et al. (2011) found that students who were exposed to allergens had a substantially higher rate of sensitisation to work-related allergens, which was linked to atopy and bronchial hyperresponsiveness, during the first 2-3 years after exposure began. After this, however, the sensitisation rate decreased.

Prevention

Driven by rapid changes in technology, such as the introduction of ventilated cages, exposure to laboratory animal allergens is decreasing; nonetheless, a recent study reported a 5-8 % prevalence in laboratory workers of sensitisation to laboratory mice (Feary and Cullinan, 2016).

The Netherlands has technical measures/environmental solutions to prevent laboratory animal allergies in the academic sector, such as equipment for cleaning cages, ventilation systems and protective clothing, which the interviewees considered to be transferable to other countries (Annex 5, Table 9). Good cooperation between universities and financial resources have made this possible, but experts have warned that there may still be a perception among laboratory workers that the risks are under control. Another factor that may impede safe working procedures and accuracy is the lack of social control in laboratory work, as laboratory workers often work alone, and they may not be under the scrutiny of co-workers or supervisors.

The Dutch focus group session (task 3) discussed a successful policy to prevent laboratory animal allergy among laboratory workers through the implementation of far advanced compartmentation with strict cleaning and clothing regimes and good ventilation, with the same rules being implemented for both personnel and visitors. During its development, a combination of organisational, technological and human factors was taken into account, and the differentiation between 'clean' and 'dirty' areas (black-white areas) was one aspect covered. Their advice included considering a combination of organisational, technological and human factors when developing (technical) solutions, as these are all important to the intervention's success. The experts stressed the importance of 'thoroughness' in setting measures for working with laboratory animals. Commitment from all concerned is crucial, meaning that the motivation of workers should be addressed when implementing interventions. Two recommendations on OSH prevention were provided in that respect: (1) implementing general (universal) policy measures with a clear set of rules that apply to everyone working in or visiting a laboratory animal facility and (2) setting strict rules for the use of personal protective equipment (PPE). Lastly, they suggested that workers could be screened before the commencement of employment for existing allergies or health problems — as is done in the triage method for sensitisation, which was developed and implemented for bakery workers — and this should help inform workers at risk in a personalised way and set preventive measures, including for vulnerable workers.

Other animal-related occupations and policy measures

The French experts mentioned several successful policy measures for other occupations involving contact with animals (Annex 5). One was aimed at improving the prevention of rare diseases among humans and animals caused by biological agents (e.g. Q fever) through surveys and monitoring people who are in contact with biological agents. Prevention management advice is also given, based on laboratory work. Another French expert reported a successful policy for field professionals in the wildlife field, aimed at promoting a culture of prevention. The measure included training in the workplace.

Agricultural workers (including animal farming)

Because of their work with crops and/or livestock, agricultural workers may be exposed to animals, animal fluids (urine, milk, etc.), animal feeds, plants and parasites. The spectrum of activities and consequent exposure to a diverse range of biological agents in agricultural work results in the prevalence of various work-related diseases in this sector. These range from outbreaks of zoonoses (Q fever) to diseases resulting from the inhalation of organic dust, a complex mixture of dust and microorganisms, which carries a high risk of exposure to bacteria, viruses, fungi or biological agent-related toxins, known as endotoxins.

According to the experts from the focus group discussions, the issues that should be monitored closely are exposure to organic dust and multi-resistant bacteria (particularly the rise in colonisations of these bacteria in agriculture — this affects both farmers and animals), both of which are linked to intensive breeding and increasingly industrialised farming; zoonotic agents (animal diseases that can be transmitted to humans, some import pathologies); and new viruses, especially respiratory agents (respiratory transmission). Some of these issues were regarded as being potentially on the rise. Moreover, these categories tend to overlap. The section 'Emerging risks' of this subchapter focuses more closely on these issues and how they could be addressed.

The occupational health experts from the agricultural sector who were interviewed mostly reported successful policies for addressing these problems (Annex 5, Table 9 and Table 10), elaborating on both facilitating and hindering factors. Some highlights are described below.

A German expert reported a wide range of measures developed for the agriculture and forestry sectors, from worker qualification programmes to research projects. In Germany, statutory occupational insurance institutions are the main institutions responsible for these programmes. According to the expert, the measures are transferable to other countries, although they must be adapted to different legal and organisational conditions. Systematic data collection yielding large quantities of consistent data makes it easier to identify the most important issues and target effective prevention efforts. However, the practical implementation of policies is often the main issue.

An important obstacle mentioned by the German expert was that, as the hazards of and solutions to preventing exposure to biological agents (called BioStoff in Germany) are not explicitly mentioned in OSH regulations, they are not the focus of those responsible, and potential health hazards are inadequately dealt with. In addition, there is a lack of awareness of the regulations. According to the expert, the level of awareness is dependent on the type of company, and its size, structure and division. Small businesses and farms often lack sufficient knowledge about biological agents and are less aware of the issues at stake. One expert mentioned a lack of awareness of risks and preventive measures as a hindering factor among agricultural workers and their employers. The expert felt that this was the case for two reasons. First, many workers on these farms are foreigners and have poor education, so their comprehension of risks, guidelines and instructions is limited by a language barrier and a poor capacity for understanding such things. Second, employers lack understanding, the ability to communicate regulations and instructions to their workers in a comprehensive way, and commitment. Annex 6 to this report includes some practical proposals to address this issue. For example, the experts envisaged that it should be a job requirement for foreign workers to be trained on how to control exposure before they start their work. A hindering factor is the attitude of farmers; farmers may have a limited perception of risk (the so-called Superman attitude), i.e. they may lack awareness and understanding of the severity of the issue and may not think that they are vulnerable, thus neglecting their own safety and health.

The facilitating factors mentioned were the practical orientation of farmers and the practical relevance of advice that fits the mentality of farmers and agricultural workers. (Note, for inspectors or consultants, it would help if the rules for protecting themselves on farms were also simple and easy to understand.) Other facilitating factors are good cooperation with farmers and actively involving the industry. It is also important that the information is practical, accurate and up to date. A practical booklet for pig farmers on reducing dust-related health risks was successful because it was accompanied by consultants who visited the farms and talked about what the advice entailed for the individual farmers and their companies, i.e. the conclusions that should be drawn from the pamphlet and what needed to be modified and adjusted. However, a consultant visit is also time-consuming and costly.

Another successful initiative was providing free testing of PPE to prevent various health problems (e.g. respiratory diseases, allergies, sore hands). For example, farmers were asked to test different types of the latest respiratory protective equipment (masks), and they experienced the difference between using and not using a mask, such as no coughing at home after work. The difference they noticed was the reason for continuing to use these masks after the research project had ended. In addition, personal contact through a consultant visiting the farm was directly related to the success of existing measures. However, working with a mouth-covering respiratory mask all day long is not considered realistic, and there are other technological solutions for working safely on a farm that may not be practical.

Zoonoses

Zoonoses were regarded as an important issue in the focus group discussions (task 3). With respect to bacterial infections, the main ones referred to in the publications retrieved in task 1 were leptospirosis (an infectious disease that can pass from rats to humans when a minor skin injury is exposed to water or soil that has been contaminated with animal urine), Q fever and tuberculosis. Q fever (caused by *Coxiella burnetii*) has been often described among dairy workers and (livestock) farmers and is mostly related to outbreaks during 2001-2010 in, for example, the Netherlands. *Coxiella brunetii* persists in the environment in a resistant spore-like form. The major infection route for farmers is via the inhalation of aerosols from urine, faeces and birth by-products. Furthermore, MRSA is a frequently reported bacterial risk.

Bovine tuberculosis is associated with airborne-acquired infection among animal keepers and meat industry workers from countries in which bovine tuberculosis remains a problem. *Mycobacterium bovis* infection in humans, however, appears to be relatively rare. In addition to infection via inhalation, dermal infection also seems to be relevant in relation to tuberculosis. Hepatitis E among pig and poultry farmers was the virus infection most often referred to in the agricultural context.

According to the Finnish experts, animals such as birds and voles are carriers of bacteria and viruses that cause a range of diseases, including nephropathia epidemica (NE) ([14]) (caused by the Puumala virus, a zoonotic virus spread through vole urine), which poses a risk of infection to farmers. For instance, bacteria-carrying birds are a problem, especially in berry cultivation. Experts from the Netherlands claimed that zoonoses, more specifically MRSA (not officially a zoonosis) and *Coxiella*/Q fever in different animals (goats, cows, calves), were considered risks in both animal husbandry and hospitals. An expert explained that goats miscarry when infected with *Coxiella* — a clear sign that something is

([14]) NE or epidemic nephropathy is a type of viral haemorrhagic fever with renal syndrome.

wrong — which may help exposed workers and farmers to identify a risk, whereas cows do not miscarry and do not give any warning to people working on a farm.

In central and eastern Europe, cases of human dirofilariasis, a parasitic disease caused by the species *Dirofilaria repens* and *Dirofilaria immitis* and transmitted by mosquitoes, are possibly zoonotic.

Overall, tick-borne diseases are well known among agricultural workers. A significant number of publications retrieved in the literature search describe tick-borne diseases related to agriculture (encephalitis, Lyme disease, Crimean-Congo haemorrhagic fever, tularaemia). In Europe, the annual number of Lyme disease cases is increasing in some areas, and tick vectors are expanding their range to higher altitudes and latitudes, suggesting that Lyme disease will remain an important health concern in the coming decades, especially in the light of economic, land use and climate change predictions. As with abattoir workers, Crimean-Congo haemorrhagic fever is endemic in the Balkans among agricultural workers, and virological or serological evidence also confirms its presence in Spain and Portugal. It could very well be spreading to other countries that are experiencing changes in climatic conditions.

In France, one expert explained that, although the literature contains many solutions for diseases transferred by a zoonotic factor, and more specifically Lyme disease spread by ticks, workers rarely know about them or search for them, either because these risks are not perceived at all or because they are just considered 'part of the job' and somehow accepted. The expert called for information related to zoonotic risks (in reference to vector-borne diseases) to be provided in a practical, pragmatic and dispassionate manner. According to this expert, the challenge would be to formulate very simple messages that can be shared, enabling people to stay level-headed, feel more secure in their knowledge of such risks and adjust their behaviours accordingly. It was claimed that there had also been instances of mortality due to chlamydiosis (a zoonotic bird disease caused by *Chlamydophila psittaci*, which can be transferred to humans).

In France, an alert system ensures warnings are exchanged to prevent the spread of emerging zoonotic diseases for which registration is not mandatory. A network of professionals from (occupational) health services in multidisciplinary teams can exchange information on alerts. The target groups are farmers, and foresters, workers in animal husbandry, environment professionals and workers at zoological parks. This measure can probably be transferred to other countries. France has an observatory of zoonoses in agriculture, managed by the CC-MSA, the statutory social insurance organisation for the sector. More information on the sector is provided in Section 3.5.2 of this report. Occupational physicians and prevention advisers are involved in every OSH service of CC-MSA. This is similar to the approach in Finland of the occupational health services in agriculture (see the subsection on organic dust in this chapter).

During the stakeholder workshop, it was mentioned that, in Hungary, zoonoses are considered a serious issue in the agricultural sector in relation to, for example, maize plants. A current trend in this sector is the reduced use of pesticides, which has, however, resulted in an increased number of rats and consequently a higher incidence of leptospirosis. Currently, in Hungary, a campaign has started in the agricultural sector that includes a targeted investigation of biological agents in the workplace.

Emerging risks

According to the focus group experts, biological agents that should be monitored in this sector are new viruses, especially respiratory agents (respiratory transmission); zoonotic agents (animal diseases that can be transmitted to humans, some importing pathologies); and multi-resistant bacteria, in particular those linked to the rise in colonisations of such bacteria in agriculture (affecting both farmers and animals), which is linked to intensive breeding. Some risks were mentioned by experts from only one specific country: experts from France were worried about emerging diseases related to poultry husbandry; experts from Germany were worried about emerging risks from organic farming; and Dutch experts were concerned about asthma due to organic dust exposure.

Multi-resistant bacteria due to, for example, the extensive use of antibiotics in farming are considered an emerging risk, one that is increasing and affecting many people. As multi-resistant bacteria are affecting both animals and humans, the increased use of antibiotics is problematic for both. The way in which animals are bred may need to change to reduce the need for antibiotics.

Experts from four countries mentioned that the industrialisation of livestock farming has resulted in high-priority emerging risks, as the process has resulted in increased size of farms (more animals, more workers) and made their production more efficient. More workers are performing specialised work, instead of carrying out all tasks, which is increasing the risk of diseases spreading more easily. In addition, depending on the type of job/task, performing a specific job or tasks for longer periods of time can lead to longer periods of (high) exposure to, for instance, organic dust among workers.

Furthermore, as pointed out by the German experts, industrialised farming in one country may result in the introduction of new biological agents in another country as more products are exported. At the same time, risks may be reduced locally because of the outsourcing of certain activities.

Despite these critical assessments of the concentration of farming in larger establishments, in general, processes and skills are considered more controlled on larger farms than on traditional smaller farms. However, according to the experts, industrialisation increases duties involving risk assessment and additional legal and documentation obligations of employers.

Transporting animals in particular is considered an important risk factor with regard to the circulation of pathogens. Regarding poultry husbandry, the French experts identified transporting animals as a significant risk for pathogen circulation. One expert mentioned that duck zoonosis was due almost entirely to animals being transported. The way the husbandry sector is now organised in France, the breeding and raising of animals are done separately by specialist operators. This implies that animals need to be transported from the company specialised in breeding to the company specialised in raising animals. There are technological solutions available to avoid exposure; for example, one innovative solution is a robot designed to catch birds.

During the focus group discussions, the intermediaries recommended the following policy measures with regard to these identified emerging risks.

- Training and information
  - The French experts talked about **educating farmers in risk prevention**. Training could be provided for new generations of farmers early on in their school curriculum. The experts considered it more difficult to reach farmers at work, and, although training in practice would probably be the best learning option for farmers, it would probably be more realistic to provide e-training on risk prevention.
- Awareness-raising
  - According to the French experts, **animal transport workers and the farmers** who own these animals should be made aware, in advance, of the preventive measures they can use to stop biological agents spreading during the journey, such as disinfecting the truck directly after the journey. Explaining that the health-related risks are connected to financial risks can motivate them.

- OSH prevention
  - The Finnish experts indicated that occupational health services should focus more on **implementing the preventive measures** in practice. According to the experts, the use of PPE is low among farmers; this is partly because they are entrepreneurs and therefore have to acquire the PPE, such as respirators, themselves, which they consider to be expensive. The experts stated that PPE usage has already improved somewhat among the younger, more educated generation of farmers. It was also discussed during the workshop that Germany has a well-established system in place that focuses on the agricultural sector: employers have to perform a risk assessment in workplaces affected by biological agents.
  - In relation to industrialisation, it was recommended that all the current technological solutions and measures offering these alternative options for specific problems on farms be mapped.
- Monitoring and inspection
  - The Finnish experts suggested **research (collecting occupational hygiene samples), monitoring and performing risk assessments** on farms. These measures should be easier to implement because agricultural companies are increasing in size and decreasing in number.
  - France has a policy measure for the reduction in exposure to biological agents in agricultural companies that receive health complaints from workers. In these companies, local measurements are performed, advice is given and assistance is provided to improve work processes to prevent infection or endotoxin exposure.
- Financial
  - The French experts indicated that subsidies in agriculture could be dependent on both production and quality, as well as **worker welfare**.

Organic dust

Organic dust and bacterial and fungal endotoxins produce a wide range of effects, including infections, toxic effects, carcinogenic effects and allergenic effects. Long-term exposure to organic dust, which includes moulds, pollens, bacteria, pesticides, chemicals, feed and bedding particles, and animal particles, including hair, feathers and droppings, can lead to congestion, coughing or wheezing, sensitivity to dust, and frequent infections, such as colds, bronchitis and pneumonia. Over time, exposure to organic dust can result in serious respiratory illnesses, such as organic dust toxic syndrome (ODTS) and farmer's lung (a type of hypersensitivity pneumonitis induced by intense or repeated inhalation of organic dusts). Several publications describe a reduction in the risk of lung cancer and immune-related effects related to organic dust (endotoxin) exposure among (livestock) farmers, whereas others indicate an increased risk of chronic obstructive pulmonary disease (COPD), interstitial lung disease and more generic airway effects such as coughing, irritation, lung function decline, chest congestion and farmer's lung. Farmer's lung is also the most reported occupational disease among farmers and agricultural workers.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In the focus group discussions (task 3), the practitioners from different countries agreed that organic dust exposure is a high priority for prevention. Animals being reared intensively (in high concentrations; many animals close together) and the fact that the sector is becoming increasingly industrialised (farms increasing in size; more animals per farm and therefore more organic dust) is leading to higher concentrations of organic dust. The experts mentioned that farmers especially need more information on how to avoid exposure, reduce dust and endotoxin concentrations, and increase the use of PPE (Annex 6).

The Danish and Dutch experts mentioned important measures to decrease or avoid workers' exposure in husbandry to organic dust, namely:

- the use of dust-free litter;
- the automation of work processes;
- the use of protective equipment.

Experts from Finland, France, Denmark and Germany agreed that more could be done to increase awareness and/or knowledge among farmers through the provision of information and training on the risks of exposure to organic dust and the negative health effects of developing a chronic respiratory disease. They need more information on how to avoid exposure, reduce dust and endotoxin concentrations, and make use of PPE more frequently and improve hygiene. Most recommendations were also applicable to farming in general. They discussed teaching farmers to perform workplace risk assessments and implement improvements (e.g. to reduce dust exposure and control dust exposure), hygiene recommendations, motivating workers to protect themselves and change the way in which they work, disseminating research results to farmers and to agricultural students via vocational schools, and aiming press releases at researchers and professionals. Moreover, it is important to inform and educate farmers on regulations and rules in a clear, understandable and practical way. Free-of-charge testing equipment would also stimulate farmers to work in a safer way.

The experts considered that the absence of OELs specific to biological agents, reliable measurements and analysis techniques was problematic as regards the risk of exposure to organic dust. The German experts reported that their limit value of inhalable dust (10 mg/m^3) was ineffective for preventing health problems, because this threshold applies solely to non-toxic dust, based on the clearance function of the lung. Even though the measurements of organic dust in the workplace were below this threshold, workers were still suffering from chronic respiratory disease.

In Finland, workers' exposure is monitored by FIOH. FIOH has developed the Finnish Job Exposure Matrix (FINJEM). Even when only a job title is known, the exposure of a worker can be estimated based on the exposure measured in large groups of workers with similar job titles that have been logged in the database for a long period of time. The types of exposure that are relevant to biological hazards in the FINJEM database are exposure to organic dusts (such as animal, flour, plant, softwood and hardwood

dust) and exposure to microbiological agents (mould spores and Gram-negative bacteria of non-human origin).

There are also groups of workers who may be more vulnerable to exposure to organic dust; these are pregnant women, people with pre-existing diseases and conditions, such as lung diseases, allergies and asthma, people who suffer from diabetes (because of the increased risk of infection) and people with (other) chronic diseases. Exposure to organic dust could be addressed by applying more stringent dust prevention measures and using protective equipment.

Annex 6 contains more detailed examples of these recommended policy measures.

Allergens

Allergens were a significant risk factor identified by two countries during the focus group discussions. In some countries, however, allergens are not considered biological agents (e.g. in Slovenia). On the topic of asthma, the Dutch experts recommended that, to learn more about its causes, asthma in agricultural settings should be monitored and registered. Health complaints may be too unspecific to be interpreted as related to work, and the sector could actively search for the occurrence of work-related health problems such as asthma, by building on experiences from existing screening programmes implemented for bakery workers (the Netherlands Expertise Centre for Occupational Respiratory Disorders — NECORD — and Utrecht University) or periodic screening in the construction industry carried out by Arbouw/Volandis.

Farmer's lung

Farmer's lung disease, a form of hypersensitivity pneumonitis, is probably the most common allergic complication among agricultural workers and may very well be one of the regularly registered occupational diseases in many EU Member States. It is caused by the inhalation of microorganisms from hay, feed or grain stored in conditions of high humidity. Farmers are exposed to large amounts of bacteria and fungi from organic dust. Activities such as cleaning storage facilities especially cause dust exposure, leading to farmer's lung. Densely packing hay in warm and humid climates has been found to correlate with an increased concentration of hypersensitivity pneumonitis-causing microorganisms. Hypersensitivity pneumonitis has also been reported in the animal- and bird-breeding industry (cattle, pig, poultry farmers), in relation to exposure to feed, bird serum, feather bloom and droppings. Furthermore, heat and humidity have been identified as risk factors, making farmer's lung disease a more common occurrence in the south of Europe. The primary agents causing the disease are thermophilic actinomycetes (bacteria), but fungi can also cause the disease. Fungal agents implicated in hypersensitivity pneumonitis in agricultural settings (such as *Aspergillus* and *Penicillium*) include those present in hay/silage, grain, mouldy sugar cane, tobacco, mouldy grapes, mouldy onions, mouldy potatoes, peat moss and mushrooms, including shiitake mushroom spores. The most common of these can be found growing on plants and are of the genera *Alternaria* and *Cladosporium*. Other researchers have corroborated the role of *Absidia corymbifera* in farmer's lung disease, as well as naming other common causative fungal agents, notably *Eurotium amstelodami* and *Wallemia sebi, Aspergillus fumigatus* and *Penicillium*, *Alternaria* and *Botrytis* (Cano-Jimenez et al., 2016). Pigeon breeder's disease is the avian counterpart to farmer's lung disease, caused by *Saccharopolyspora rectivirgula* and exposure to bird proteins.

Farmer's lung is monitored and registered in the United Kingdom (reported under ill health assessed for disablement benefit — Industrial Injuries Disablement Benefit, IIDB) and France (RNV3P national database). In Finland, studies have been conducted that have collected data on farmer's lung since 1987 (Louhelainen et al., 2017; EU-OSHA, 2018a). Despite the large amount of information already available, farmer's lung is still an important issue in the farming sector, and currently 10–50 types of farmer's lung disease are reported in Finland, which is fewer than in the past. There is an ongoing revision of occupational healthcare recommendations, and the guidelines (the so-called blue book) on the screening practices to diagnose occupational asthma or identify at-risk individuals have also been revised.

Regarding policy measures, a Dutch expert mentioned a lack of measures for the prevention of allergies among farmers and farm workers caused by exposure to fungi and animals in the agricultural industry. Workers with such allergies often have to leave their workplace/employer, because avoiding exposure is seldom realistic in practice.

However, Louhelainen et al. (2017) reported on the establishment of OSH services for farmers in Finland based on recommendations from an extensive research and pilot project in the 1980s. Studies focusing on exposure and risk assessment in farming showed that farmers were highly exposed to different types of airborne impurities, biological dusts, including fungi, bacteria and endotoxins, animal dust and storage mites. A training programme for occupational physicians, nurses and physiotherapists, as well as agricultural advisers (a group of trained experts who support farmers in implementing OSH measures), was initiated. The structure of the training for farmers' occupational health personnel has remained almost the same since 1980: theoretical training (2 days) and a practical farm visit (a walk-through, 1 day). In 2000, a guide (*Good occupational health practice in farmers' occupational health services*) relying on information from law enforcement agencies, several studies from the 'Occupational Health in Finland' series and instructions from authorities and insurance institutions was developed.

Farmers have been able to voluntarily sign up for occupational health services since 1979. Usually, a plan of action is set up in cooperation with the farmer at their premises. Affiliated farmers undergo a health examination, which is repeated on demand (every 2-4 years). After a few months, an occupational health nurse and an agricultural adviser carry out a farm visit. The farm visit includes a basic analysis of the work tasks, the materials used and the types of hazards, including biological agents. The farmers receive a development plan to familiarise themselves with the health hazard, and instructions for corrective actions. Farm visits are repeated every 2 years, but the intervals between visits may vary between 1 and 4 years, depending on demand.

Studies have assessed the effectiveness of the good occupational health practice implemented by the programme. Two surveys conducted among farmers in 2004 and 2014 via computer-assisted telephone interviews showed relatively good coverage of the Finnish farmers' occupational health services (FOHS) in all production lines and increased coverage from 2004 to 2014. Studies have also assessed the effectiveness of the services regarding good occupational health practice.

The role of FOHS in occupational medicine and the recognition of symptoms and diseases in farmers has been very important. However, one obstacle in risk assessment is the lack of instruments to measure and identify biological agents, meaning that visual judgement and experience are relied on. Emerging risks, such as multi-resistant bacteria and respiratory viruses, have also been addressed by FOHS, with the help of veterinary and healthcare experts. Changes in exposure patterns have been observed over time, and the most obvious reasons for this are changes in work procedures and production methods in agriculture.

Antibiotic resistance

As mentioned above, the focus group experts raised the issue that a high concentration of animals in husbandry causes diseases to spread more easily, leading to the over-use of antibiotics to prevent infection outbreaks. This, in turn, is one of the causes of antibiotic resistance in bacteria in this sector. Experts from almost all countries agreed that multi-resistant bacteria were the number one emerging risk in need of additional policy measures.

In the experts' interviews (task 2), most of them indicated that biological agents are not a priority at the national level, which limits resources for developmental projects, research, inspections and consultations. Although MRSA is the exception, experts indicated that much is still unknown, even in the case of MRSA, and more research, national action, legislation and regulation are needed. The experts reported that motivation to improve the current situation was an important success factor, as well as broad cooperation between many relevant organisations, which in one case had resulted in a commitment to develop a national strategy on the prevention of MRSA infections. However, daily press attention, for example in the case of MRSA, often causes uncertainty among those working in animal husbandry and stops policy measures from successfully preventing infectious diseases and allergies in agriculture and forestry.

Policy measures to reduce the use of antibiotics in farming (for more details, see Section 3.1.2 and Annex 6) included the following.

- Training and information
  - The Danish experts saw a need for **better information, education and training** for people working in the sector, to reduce farmers' use of antibiotics for animals.
  - The Finnish experts recommended **personal counselling and guidance** from healthcare professionals for farmers on recognising multi-resistant agents and (alternative) treatments.
- Design of technological solutions
  - The French experts made it clear that, to reduce the risk of exposure to multi-resistant bacteria, **trends in production, changing breeding techniques and workers' well-being** (including preventive measures against exposure to biological risks) should be taken into account **when building agricultural facilities**, through ergonomics and design. Good ventilation was given as an example.
  - According to the French experts, **farmers** should be made aware of alternative strategies to using antibiotics for their animals. A French expert claimed that **breeders and veterinarians** could develop new ways of caring for their animals without using antibiotics. It was noted that breeders are professionals who do not prescribe their own medicines but are able to obtain products at the EU level that are not available in France. In addition, some experts asked for **models for calculating risks** as part of business models, although others considered it dangerous to connect risk prevention and cost analysis.
- Health surveillance
  - The Finnish experts recommended **health checks** for farmers regarding multi-resistant bacteria such as MRSA.
  - The German experts discussed providing **information for farmers** to make them aware that they should **inform physicians** about their work when they need medical help themselves. Farmers should emphasise to physicians that their work with animals entails the usage of antibiotics and the possible presence of multi-resistant bacteria.
- Regulation and policy planning
  - To reduce the use of antibiotics in animal farming, the Danish experts proposed **more rules and regulations**. However, they wondered what effect stricter rules and regulations would have locally if it continued to be possible to cheaply produce animal products for other countries without these restrictions.
  - The German experts questioned whether **new legislation on the use of antibiotics** should be part of occupational safety legislation or part of veterinary medicine legislation, and whether this was an issue concerning biological agents or dangerous materials.
- Other:
  - The Danish experts talked about raising awareness **among consumers of the risk of multi-resistant bacteria** due to the use of antibiotics when animals are bred in high

concentrations. If consumers were willing to pay higher prices for meat, farmers would probably change the conditions in which they keep their animals.

- According to the French experts, awareness among **the public of how animal health and human health are connected** (the importance of preventing multi-resistance, reducing the use of antibiotics, and understanding zoonoses and infection by zoonotic vectors) could pressure farmers into changing the way they breed their animals and searching for alternative methods to using antibiotics.

As an example of multi-resistant bacteria, MRSA in pig farms was mentioned. The Finnish experts considered pigs to be a significant source of disease in agriculture. The Danish experts talked about a programme, aimed at the owners of pig farms, that had been designed to prevent MRSA infection, and the spread of MRSA and other biological agents. The APV[15] risk assessment tool that supports companies provides information on risks in specific workplaces and recommendations for improving risk management. Training for safety representatives is also provided. Another policy in Denmark is directed towards the prevention of the spread of MRSA and other bacteria, fungi and viruses **among consultants visiting farms**. Like the inspectors, consultants have guidelines with instructions on how to behave. Films and other instructions are also available.

Arable farming

A lot of the information relevant to arable farming has already been given in the section on agricultural workers above. Because of their work with crops, agricultural workers in the arable farming sector (excluding agricultural workers working with animals) are exposed to a wide range of biological agents that are related to various diseases. To indicate the dimensions and distribution of occupational diseases in agriculture, two EU-OSHA reports highlight the fact that, in Poland in 2010, the most common diseases were (allergic) pneumoconiosis (26.9 %) and infectious and parasitic diseases (24.9 %) (EU-OSHA, 2019a, 2019b, 2019c). In that country, the incidence of disease was 418.5 per 100,000 workers among agricultural workers and foresters. Infectious and parasitic diseases predominated among the most commonly recognised diseases (92.4 %), and Lyme disease was the most common of those (96.7 %).

[15] In Danish health and safety legislation there are some risk assessment requirements that a company must always adhere to. These are described in a guideline by the Working environment authority available at https://at.dk/en/regulations/guidelines/risk-assessment-apv-d-1-1-3/

Besides the occurrence of farmer's lung in agricultural workers, it is a predominant disease in arable farming. Information on the onset of and the agents responsible for the disease is given in Section 3.1.1 of this report.

Working in agriculture (greenhouse workers, gardeners) is also related to occupational anaphylaxis, which can result from a range of allergenic agents in the sector.

Policy measures for arable farming

Table 15 of Annex 5 provides an overview of successful policy measures in arable farming that the experts reported. Annex 6 to this report includes the different policy measures recommended by intermediates in regard to current and emerging risks to improve safety for agricultural workers, such as workplace risk assessment using an adapted tool, providing information on risks in specific workplaces, and demonstrations/try-outs of the latest developments in protection materials for farmers. Other policy measures are specific storage methods for hay and grains.

3.1.2 Health care

Of all the risk sectors, literature on the healthcare sector delivers the most abundant information on work-related diseases due to exposure to biological agents. An overview over the biological agents and related health problems is provided in the literature review and a related discussion paper (EU-OSHA, 2019a, 2019e). The experts recognised the complexity of the risks that workers are exposed to in the healthcare sector in both the literature review and the qualitative research. Health care was identified as one of the sectors best covered by research and prevention, and according to the stakeholder survey health care emerges as the best-covered sector as regards guidance and detailed rules. There are also rules or recommendations establishing vaccination regimes to better protect workers from infection with biological agents. Quite a few respondents referred to obligatory reporting and record-keeping of certain exposures to biological agents, in implementation of Article 11 of the Biological Agents Directive.

However, health care is still considered a high-risk sector for exposure to biological agents. The diseases primarily described are influenza, tuberculosis, hepatitis and human immunodeficiency virus (HIV) infection, and the majority of healthcare worker-related publications that were identified in the literature search relate to hepatitis B virus, hepatitis C virus or HIV infections via sharps or needlestick injuries. The possible transfer of biological agents from healthcare workers to patients falls outside the scope of this review and is not considered here. In addition to the transmission of viral diseases via needlestick injuries, Pedrosa et al. (2011) also investigated other exposure pathways for healthcare and laboratory workers to become infected with sometimes serious viral diseases and found that aerosol inhalation was also an important pathway, for example for lymphocytic choriomeningitis virus, hantavirus and coxsackievirus infections.

The experts also agreed on which biological agents pose high-priority emerging risks in the healthcare sector. Except for the experts in Germany, all agreed that agents with antibiotic resistance are the most significant emerging risk and should be the focus in the healthcare sector. MRSA and infectious diseases caused by blood-borne pathogens are both listed by three countries as highly important. The experts also identified infectious diseases caused by blood-borne pathogens and accidental exposure as emerging, potentially increasing risks. In relation to accidental exposure, which was mentioned by both France and the Netherlands, it was reported that the healthcare sector in France is expected to face an increased workload, which may increase the risk of accidental exposure for workers (more work means more risk of exposure, and it may also lead to stress, which can cause accidents and errors). This is a trend that, most probably, can also be observed in other countries with an increasingly ageing working population (including those working in the healthcare sector) and therefore an increasing average morbidity rate. The restructuring of the healthcare sector is also an issue that may put a strain on existing health systems and consequently the healthcare workers.

The focus group experts' concerns were very similar regarding specific viruses and bacteria affecting the healthcare sector, especially multi-resistant strains. Blood-borne viruses or children's diseases were also addressed. The experts from Denmark and France added allergens (plant-derived natural products) to their list of current priorities. There are, however, issues highlighted by the literature review and the

questionnaire survey (task 1) that were not mentioned in the qualitative research, for example the occurrence of *Legionella* linked to water cooling or heating systems in hospitals.

Interviews with experts and the focus groups with practitioners confirmed these findings, and many issues identified in the literature review, stakeholder survey and extraction from selected monitoring systems were reflected in these discussions. The experts from Denmark did not consider the healthcare sector to be as problematic as animal-related occupations and the waste treatment sector. They elaborated that the healthcare sector is very well regulated and that workers are very capable of following regulations. The implementation of rules is also controlled internally by, for instance, specially educated nurses. Healthcare and veterinary services are indeed known for the high level of implementation of regulation and control measures. In general, workers active in these sectors are likely to be better trained and more aware of the risks they are exposed to. During the stakeholder workshop, participants discussed how the healthcare sector should be divided into three subsectors (home care; clinicians; and general practitioners, GPs), as exposure to biological agents differs considerably as a result of different (work) environments. Nurses and doctors are considered well-trained people, but many other workers in hospitals are unskilled, such as cleaners and laundry workers, trainees and temporary workers, and foreign workers. The Finnish experts recommended the following two measures: (1) the provision of information and counselling with occupational health service providers and (2) repetitive training and instructions on protective measures such as PPE and hand hygiene. The experts agreed that instructions should be followed at all times, with no exceptions.

To further improve the situation in workplaces, the experts recommended additional policy measures in the categories of training and information, awareness-raising, regulation and policy planning, and financing. The emphasis was on continuous/repetitive training and information, which are needed by all workers in the healthcare sector, for medical workers (role models) as well as non-medical workers (e.g. cleaning personnel) and temporary workers. The discussions targeted not only infectious agents but also allergies. For the risk of allergens, the Danish experts recommended introducing targeted learning courses (education on law, prevention and information) for all kinds of workers, including those not directly involved in health care, such as cleaning personnel. They also recommended obligatory (e-)courses and targeted campaigns.

Policies and practices in the healthcare sector were also discussed during the stakeholder workshop, and participants identified proper communication between authorities and hospital experts responsible for hospital hygiene (encompassing, for example, disinfection rules) and OSH authorities and responders at the level of the individual establishment (hospital, care facility, outpatient clinic) as essential to ensure that good prevention is in place to limit exposure to biological agents.

It should be mentioned that the measures outlined in Directive 2000/54/EC include special control measures, such as containment categories for laboratory work and industrial processes, and special attention is paid to healthcare and veterinary care facilities. The list of biological agents included in the directive also gives a separate indication of cases in which biological agents are likely to cause allergic or toxic reactions, an effective vaccine is available, or it is advisable to keep a list of exposed workers for more than 10 years.

Occupational diseases

The exploration of monitoring systems for work-related diseases from exposure to biological agents in health care confirms the issues identified by the literature.

There is a limited number of occupational diseases recognised, namely tuberculosis, blood-borne viral diseases such as hepatitis and HIV infection, and some other infectious diseases such as scabies. In a review by Dulon et al. (2015), the most frequently recognised occupational infectious diseases in Germany were latent tuberculosis infections, active tuberculosis and hepatitis C. Scabies was mainly relevant to geriatric care. Although occupational blood-borne hepatitis infections have become rarer, the authors warn that the clinical course may be severe, so the risk of an occupational infection is still worthy of attention. Most of the notified diseases (39 %) were reported in hospitals, 21 % in elderly care and nursing facilities, 16 % in medical practices, and 5 % in outpatient services. Taking into account the number of employees, this is an average of 20 notifications per 100,000 employees.

In addition to infectious diseases, healthcare occupations are also among the occupations with the highest rates of work-related skin diseases.

Latex glove exposure has been linked to asthma and anaphylaxis in dental technicians, healthcare workers and glove manufacturers (Moscato et al., 2011; Quirce and Bernstein, 2011; Raulf-Heimsoth et al., 2011; Raulf-Heimsoth et al., 2012; Moscato et al., 2014; Raulf, 2016).

Vaccination

Vaccination is one possible prevention measure and considered highly effective by the experts included in the qualitative research of this review, which is why it was mentioned many times as a policy measure for protection from a variety of risks in the healthcare sector, often in combination with other measures. Germany, for example, referred to its policy in the healthcare sector to protect workers, company doctors and employers in hospitals and day-care centres from infection from pathogens, such as, hepatitis B and children's diseases, zoonosis, and exotic and tropical diseases. The measures taken are consultations on vaccinations and the vaccination of workers.

The list of agents with effective vaccines in Annex III to the Biological Agents Directive are *Bordetella pertussis*, *Clostridium tetani*, *Corynebacterium diphteriae*, *Mycobacterium africanum/bovis* and *tuberculosis*, *Neisseria meningitidis*, *Salmonella paratyphi A, B* and *C*, *Salmonella typhi*, Rift Valley fever, Central European tick-borne encephalitis virus, Japanese B encephalitis virus, the viruses causing Kyasanur forest disease, Omsk haemorrhagic fever, Russian spring-summer encephalitis (TBE), Eastern, Venezuelan and Western equine encephalomyelitis, yellow fever, hepatitis A, B and D, influenza viruses types A, B and C, viruses causing measles, mumps, rubella and polio, monkeypox virus, variola (major and minor) virus, whitepox virus ('variola virus') and the rabies virus. Some of these biological agents cause common diseases, including childhood diseases, some are transmitted by vectors such as ticks, and some may be transmitted by blood-borne infections. Some diseases are also re-emerging, such as tuberculosis. Quite a number of those are classified as Risk Group 3 organisms (which can cause severe human disease and present a serious hazard to workers; they may present a risk of spreading to the community, but there is usually effective prophylaxis or treatment available). The fact that there are vaccination programmes within EU Member States for diseases such as pertussis and malaria, which are most commonly associated with developing countries, suggests that some

countries (e.g. the Netherlands, the United Kingdom) recognise the importance of migration and (work) travel in relation to the distribution of diseases from outside the EU.

Vaccination should be carried out in accordance with national law and/or practice; workers should be informed of the benefits and drawbacks of both vaccination and non-vaccination, and vaccination must be offered free of charge to workers, according to the directive.

A number of reviews identified in the literature review targeted vaccination and the willingness of workers in the healthcare sector to be vaccinated, as well as the level of awareness among workers. Vaccination is a measure that is mentioned regularly, especially regarding healthcare workers, in this review.

As the literature review concluded, a better understanding of the factors influencing low vaccination take-up among healthcare workers is an important subject for further research. It is not fully understood why there are low vaccination rates against, for example, influenza and *Bordetella pertussis* among healthcare workers, as pointed out in some of the research identified in the review, but vaccination rates may be important when it comes to the protection of workers and patients. Kuster et al. (2011), for example, pointed out that healthcare workers are at a higher risk of asymptomatic, but not symptomatic, influenza infection; this may mean a potentially increased risk of transferring infections to their patients and may also be important to consider in the event of a pandemic outbreak. A higher rate of asymptomatic infection suggests that past exposure has led to a certain degree of immunisation; however, the infection rate would not be recognised, as it is asymptomatic. As a result, those healthcare workers may spread the disease. As the authors point out, a thorough assessment of influenza risk in healthcare workers is needed to support decisions regarding priorities for influenza vaccination and antiviral treatment or prophylaxis during pandemics. In the Netherlands, at academic hospitals, hygienic work practices and seasonal flu vaccinations focus primarily on the protection of patients and secondarily on workers. The patients' safety (which healthcare workers consider important) is a facilitating factor for this measure. Furthermore, constant innovation using monitoring and evaluation of incidents and the availability of financial resources improve conditions for both workers and patients. However, there is still a lack of cooperation between occupational physicians, industrial hygienists and safety experts.

Similarly, vaccination rates linked to other diseases may have to be considered not only to prevent the spread of diseases, particularly to vulnerable populations, but also to limit the amount of risk to the workers themselves. Fiebelkorn et al. (2014), for example, analysed vaccination rates of healthcare workers against measles. The risk of acquiring measles was reportedly estimated to be 2 to 19 times higher for susceptible healthcare personnel than for the general population. Half of European countries were found to have no measles vaccine policies for healthcare personnel, according to this study. Considering the resurgence and outbreaks of measles in some Member States, this is an important finding that should be followed up. This is a particular issue for young healthcare workers, as they were found to be more susceptible, according to this study. Another topic identified in the review was immunisation against pertussis, especially regarding vulnerable groups.

However, some countries did report vaccination programmes for healthcare workers in the stakeholder survey that was conducted as part of the literature review, most of which were related to hepatitis B and efforts to increase flu vaccination rates among healthcare workers. Lastly, vaccination against tetanus and vaccination against tick-borne encephalitis are relevant to workers who are in contact with soil or prone to tick-borne diseases, for example when working outdoors or with animals.

The French experts also considered that there is a need to bring the healthcare issues to the attention of national decision-makers and promote awareness of, for example, low vaccination rates. This is expected to stimulate political decision-making and thereby facilitate the implementation of the measures. Regarding vaccination rules for caregivers, French experts considered it counterproductive that hepatitis B vaccination in France is mandatory for all professional caregivers. Some healthcare workers are worried that the vaccination leads to other health problems and therefore reject it. The expert recommended making the vaccination strongly recommended rather than mandatory, as is the case in other EU countries. Risk education provided very early on in professional training and refreshed regularly would help increase vaccination rates.

There are different views on this: according to the New Infectious Disease Act in Finland, for example, a worker should not be employed for a specific job without the necessary vaccines. Finnish experts also recommended immunisation and information campaigns on vaccination, with correct and suitable information for the public to prevent false information, and attention to the admittance of visitors to reduce the risk of bringing disease agents (e.g. multi-resistant bacteria) into the hospital.

Multi-resistant strains

In the literature review, quite a few articles were retrieved that discussed hygienic measures to prevent the spread of microorganisms with multiple antibiotic resistance and nosocomial infections in the healthcare environment, some focusing, for example, on issues such as clothing and mobile phones as a factor for transmission. During the focus group sessions, the experts from Finland, France and the Netherlands indicated that they considered biological agents with antibiotic resistance, such as MRSA, to be an emerging risk in health care that requires additional measures. Measures should aim to improve the prescription of antibiotics, prevent the spread of agents with antibiotic resistance among healthcare workers and patients and within hospitals, and improve immunisation. More details are given in Annex 6. The measures recommended by the experts from these three countries are summarised in the subsection ‘Proposed measures’ below.

In addition to the issues addressed below, globalisation is considered a huge problem, especially with regard to agents with antibiotic resistance, because it increases the likelihood of a global spread of diseases. This will, in turn, put pressure on existing health systems, and local health systems are likely to have to deal with global health problems. This could very well be observed not only during the 2020 outbreak of coronavirus disease (COVID-19), but also during the Middle East respiratory syndrome coronavirus (MERS-CoV) and severe acute respiratory syndrome (SARS) epidemics.

According to the literature review, networks of experts can make a very valuable contribution to an assessment of the situation and provide valuable information to public and occupational health stakeholders: a Dutch expert network has contributed to the characterisation of multi-resistant microorganisms and issued assessments of the risk levels, and other networks directly contribute to prevention and new legislation. It is important to note that the assessments of microorganisms are

carried out by different ministries in some Member States (European Commission, 2017), notably the ministries of health, and collaboration between public health and OSH experts (and their networks) should be ensured to maximise the benefit of their knowledge and input.

The Dutch experts thought that it was necessary to formulate clear policy measures that are aimed at reducing the use/prescription of antibiotics — antibiotic prescription is still very common in current protocols that are used in the event of infection. First, they recommended checking the current guidelines for prescribing antibiotics, to resolve this issue at the source, and whether or not reduction in use is taken into account when new guidelines are developed. Furthermore, differences within the healthcare sector in how easily antibiotics are made available to patients are suspected'. Also, it can be assumed that not all patients finish their course of antibiotics, which should be taken into account. Second, when setting regulations, how waste is handled should also be taken into account, to prevent antibiotics being further distributed into the environment. Third, the experts indicated that national rules and regulations should be compared with EU rules and regulations on this topic, as they should preferably be aligned, and wondered if this was in fact the case.

One issue relating to the spread of biological agents with antibiotic resistance was mentioned by the Finnish experts: although there are no reported cases of MRSA infection in the healthcare sector in Finland, and currently applied hygienic measures (such as washing hands with antibacterial soap) are considered sufficient preventive measures, farmers visiting healthcare facilities may pose a risk, and there may be a spillover from agriculture and the animal-breeding sector into the healthcare sector. The issue and possible prevention measures have been addressed in Section 3.1.1 of this report. For example, it was recommended that farmers should inform medical staff that they use antibiotics in animal breeding so that possible transmissions of agents with antibiotic resistance could be taken into account in their treatment as well as in the workplace measures to protect healthcare workers who treat the farmers or provide them with care services. With the increasing industrialisation of the agricultural sector and the related increase in the size of farms and number of animals on these farms, this issue is expected to become more important.

Proposed measures

- Training and information
  - Increase awareness among workers by offering information, instruction and guidance. Provide regular training and instructions (by OSH providers) on protective measures such as PPE and (hand) hygiene, to improve understanding of hygiene among all healthcare personnel, including nurses, home assistants and private healthcare providers, to prevent the spread of agents with antibiotic resistance.
  - Advocate best practices for prescribing antibiotics with physicians (including an overview of which antibiotics can be used or should not be used, depending on the situation).
- OSH prevention
  - Practise immunisation, in combination with an awareness-raising campaign aimed at the general public on the importance of immunisation through vaccination. This should be based on suitable and accurate information (from scientists) to improve vaccination rates. In France, an expert called for a 'balanced' information campaign on public health policies, such as vaccines and medicines, with information from scientists, so that the public can make well-informed decisions.
  - Provide sufficient quarantine/isolation premises (including in older hospitals) to isolate patients with serious and highly infectious diseases. According to the French experts, farmers might be infected with work-related MRSA. Therefore, when farmers visit healthcare facilities, they should be isolated from other patients to prevent the spread of possible infections.
  - Pay attention to visitors who are welcome but may pose a risk of bringing diseases into the hospital.
- Monitoring

    - Monitor how preventive measures on hygiene are adopted by all healthcare workers and address negligence. The experts considered that preventive measures are dependent on how people adopt them (the human factor). Instructions for medical workers should always be followed, with no exceptions. Whether or not workers follow the instructions must be monitored and negligence must be addressed. The hierarchy of controls is important for deciding what preventive measure to use.
- Wider measures
    - Dutch experts advise that **protocols/guidelines for prescribing antibiotics** to patients should be reviewed, to ensure that antibiotic resistance is taken into account. This would prevent the spread of agents to patients and within hospitals.
    - By reviewing the entire chain of events regarding the development of multi-resistance ('helicopter view'), including the use of antibiotics in animal farming and waste treatment (further distribution of antibiotics in the environment through, for instance, surface water), improvements can be made to tackle this problem.

Viral infections through needlestick injuries

Infections with blood-borne viruses through needlestick injuries are one of the main risks identified by the qualitative research among experts and practitioners in this review, as mentioned above, and are also one of the main issues addressed in the scientific literature and the stakeholder survey in task 1. In addition to needlesticks and sharps, injuries may also be linked to the use of catheters (Hadaway, 2012), which is increasing, for example, in interventional cardiology (Smilowitz et al., 2013).

The Dutch experts mentioned needlestick injuries as the most significant cause of blood-borne infections such as hepatitis B. This is also related to the limited use of safe needles, for a variety of reasons. According to the literature review (EU-OSHA, 2019a), the healthcare sector is responsible for a considerable part of the incidence of hepatitis A, B and C in the recognised occupational infectious diseases reported in 12 European countries in 2001 (Eurostat, 2010). It is estimated that 14.4 % and 1.4 % of hospital workers are infected with the hepatitis B virus and hepatitis C virus, respectively. The highest prevalence of hepatitis B among healthcare workers is reported among dentists, which demonstrates that this occupational group is at greater risk of contracting hepatitis B. However, the prevalence of hepatitis C among dentists is reportedly similar to that among the general population. Hepatitis C-infected people serve as a reservoir for transmission to others and are at risk of developing chronic liver disease, cirrhosis and primary hepatocellular carcinoma. It has been estimated that hepatitis C accounts for 27 % of cirrhosis cases and 25 % of hepatic cancer cases worldwide (Alter et al., 2007), and healthcare workers are at increased risk. Likewise, an estimated 257 million people are living with hepatitis B virus infection (defined as hepatitis B surface antigen positive). In 2015, hepatitis B resulted in 887,000 deaths, mostly from complications (including cirrhosis and hepatocellular carcinoma). The hepatitis B virus can survive in dried blood for up to 7 days at 25 °C and is significantly more infectious than either hepatitis C or HIV, with a reported transmission rate of up to 30 % from needlestick injuries (WHO, 2018). Hepatitis C infections were also linked to dialysis centres (Shaheen and Idris, 2015). These figures illustrate very well the seriousness of the issue and the importance of avoiding infections through needlestick injuries in healthcare workers.

Medical procedures that pose an injury risk are those executed with sharps and needles; thus, they also pose a clear risk of seroconversion for hepatitis B and HIV. The literature search revealed a great number of publications on this issue. According to Goniewicz et al. (2012), the most often executed procedures posing an injury risk among healthcare workers worldwide when on duty are intramuscular or subcutaneous injection, taking blood samples, intravenous cannulation and repeatedly replacing the cap on a needle that has already been used. Factors affecting the risk of infection include the type of needle (closed or hollow), HIV RNA (viral load) levels and the volume of inoculated blood, and the depth of injury.

In the interviews with the experts (task 2), the French experts mentioned successful policies targeted at healthcare professionals to prevent blood-exposure and blood-borne infections (e.g. acquired immunodeficiency syndrome — AIDS; hepatitis B). The measures included:

- risk education/information regarding biological risks;
- development of protective clothing and equipment;
- vaccination rules for professional caregivers;
- national surveillance of accident types and the circumstances surrounding blood-related infections, prioritising the prevention of risks.

A Danish expert, however, explained that data on effectiveness will never be completely accurate or available within a short time span. Not all accidents are reported, and the data available are not up to date (only preliminary data from 2014 were available). As a result, it will probably take years before any conclusions can be drawn regarding effectiveness.

One expert described a good practice for the training of temporary workers, a project called 'Best Practice Sharp Instruments in Healthcare'. This project includes new regulations and combined biological exposure and sharp instruments. One element of the project is a video tutorial that is constantly on display.

In Denmark, measures to prevent needlestick injuries were promoted in cooperation with trade associations. Policies for preventing infection with hepatitis B, hepatitis C and HIV are successful in Denmark, because, in the hospital work environment, employers pay a great deal of attention to prevention.

Since 2008, many organisations have transitioned to using safe needle systems. However, this transition is not (yet) complete within the sector, and the experts gave several reasons for this. Safe needle systems are not always available in workplaces (depending on the purchasing policy of the employer or what is offered by the supplier), or they are not yet developed for a specific purpose (flu vaccinations, taking blood). On the side of the producer, a cost-benefit analysis of safe systems may have revealed that the cost of development outweighs the (expected) revenue. Therefore, during the focus group discussions (task 3), the Dutch experts recommended making **safe needle systems** more widely available. It would also be helpful to make a list of unsafe needles and needle systems, combined with information on safer alternatives, available. In addition, they mentioned that home care situations might add to the risk of needlestick injuries, and, even though caregivers are not required to, they might help with administering drugs, for example to diabetes patients. Home care patients often purchase their own materials, including needles, which may not always be safe needle systems. Finally, patients might be unaware of or choose to neglect instructions from pharmacies about how to properly dispose of needles after use (which in turn causes problems in the waste collection and treatment sector).

The experts commented that EU-level policy action, in addition to regulations at the national level, is necessary. If it is mandatory at the EU level to use safe needle systems and destroy old needle systems, this may be an incentive for suppliers or producers to develop more of these systems. Training and information are also important for the implementation of safe needle systems, as workers may not be used to these systems, or may find other needle systems easier to use or more precise. It was also proposed that the implementation and the use of safe needle systems be subsidised (possibly by return of costs from health insurance companies).

The French experts discussed the fact that an increased workload might increase the risk of accidental exposure for workers (more work means more risk of exposure, and it may also lead to stress, which can cause accidents and errors).

EU Directive 2010/32/EU on the prevention from sharps injuries in the hospital and healthcare sector implements the Framework Agreement on prevention from sharp injuries in the hospital and healthcare sector signed by the European social partners the European Hospital and Healthcare Employers' Association (HOSPEEM) ([16]) and the European Federation of Public Service Unions (EPSU) ([17]) on 17 July 2009, which is an annex to this directive. The purpose of the directive is to implement the framework agreement to:

- prevent workers' injuries caused by all medical sharps (including needlestick injuries);
- protect workers at risk;
- set up an integrated approach establishing policies in risk assessment, risk prevention, training, information, awareness-raising and monitoring.

The directive applies to all workers in the hospital and healthcare sector. Employers' and workers' representatives must work together to eliminate and prevent risks, protect workers' health and safety, and create a safe working environment, following the hierarchy of general principles of prevention, through information and consultation. Thorough risk assessment must be carried out when injury, blood or other potentially infectious material is possible or present. It should focus on how to eliminate these risks. The risk management measures are:

- specifying and implementing safe procedures (including safe disposal);
- eliminating the unnecessary use of sharps;
- providing safety-engineered medical devices;
- prohibiting recapping;
- a coherent overall prevention policy;
- training and information;
- personal protective devices and offering vaccination.

Workers should report any accident to the responsible person; the accident should be investigated and the victim treated.

HOSPEEM and EPSU have conducted a joint EU-funded project 'Promotion and support of the implementation of Directive 2010/32/EU on the prevention of sharps injuries in the hospital and healthcare sector'. Following three regional workshops and a final conference, the European social partners produced a final report that summarises the findings of a survey of the member organisations (HOSPEEM/EPSU, 2013), and have collected guidelines, handbooks and toolkits at international, European and national levels. The report provides a series of recommendations for policy and practice and information from the national level, and dwells on the reasons for the under-reporting of needlestick injuries in the hospital environment and the lack of reliable and comparable data (the number of needlestick injuries being roughly estimated at 1 million annually).

HOSPEEM and EPSU also conducted a recent survey among the EU Member States on the state of the implementation of the directive, and a report summarising the results (HOSPEEM/EPSU, 2019) provides a number of recommendations to policy actors and establishments. For instance, trade unions reported deficits with regard to certain categories of workers (non-permanently employed staff such as trainees, students or interns; newly employed workers; temporary agency staff; part-time staff working only at the weekends or at night), who are excluded because of national regulation or procedures, when it came to access to training and/or the actual provision of information on the risks and training to prevent or reduce them. A lack of economic resources to provide safe medical sharps of the quality or in the quantity needed was reported from some countries. Among the measures proposed are also proposals to include, in the risk assessment and the analysis of work processes and situations, aspects on the concrete handling of devices by individual health workers/professionals and organisational and social factors affecting the health and safety of workers and patients, and proposals to fully involve existing

([16]) HOSPEEM represents, at the European level, national employers' organisations operating in the hospital and healthcare sector.
([17]) EPSU represents 8 million public service workers across Europe.

OSH committees and representatives of management and workers and/or trade unions in such risk assessments.

Outbreaks of serious diseases and epidemics

In the focus groups (task 3), Finnish experts stressed the necessity of preparing for exceptional conditions and the need for a **contingency plan** for epidemics or infections with serious health consequences (including outbreaks of multi-resistant viruses and bacteria). Other prevention measures consisted of in-hospital measures, such as sufficient isolation/quarantine premises, paying attention to visitors who might pose a risk of bringing diseases into the hospital, and designated areas and procedures to ensure the isolation and examination of infected persons. According to the experts, no money (at the national level) is reserved for exceptional conditions, such as the need to protect workers from an Ebola outbreak. Such exceptional conditions linked to the pandemic spread of zoonoses can also originate from other sectors, such as animal breeding, and can affect workers along the supply chain, for example transport workers and those working in waste management. For instance, a disease may originate from cattle and affect workers in agriculture, slaughterhouses and the food chain, as well as transport workers; the cattle may then have to be slaughtered and disposed of by waste workers. Therefore, a contingency plan that works across sectors, with accompanying finances dedicated to the protection of workers, is needed.

Hersi et al. (2015) reviewed the protective measures, in particular PPE, for workers caring for patients with filovirus diseases such as Ebola and Marburg virus infections for the World Health Organization (WHO) guidance on the topic and recommended the provision of training to healthcare workers in affected regions as a 'key strategy' for preventing transmission. WHO developed job aids for healthcare workers on how to put on and remove PPE, and also provided them with training on clinical management. The case of an auxiliary nurse infected in Spain by an Ebola patient returning from an endemic region (WHO, 2014) illustrates that, to avoid cases of serious diseases, similar prevention approaches need to be taken in Europe. A preparedness plan is essential for coping with the importation of such diseases and limiting their subsequent spread (Wong and Wong, 2015). An article written by Lupton (2015) captures the author's own experience of working in a treatment centre in Sierra Leone, to inform healthcare workers considering deployment to West Africa to work in a treatment centre.

The German experts agreed that all workers in health care should be informed of how to deal with the increased risk of the occurrence of biological agents of higher risk groups. Workers in smaller hospitals and outpatient medical care should be included. The experts advised on developing emergency plans for pandemic situations. Financing or subsidies should be made available to help smaller hospitals and outpatient medical care facilities purchase PPE for workers in the event of an incident involving biological agents of higher risk groups.

According to the literature review, healthcare workers working abroad are at risk of acquiring some emerging infections such as MERS-CoV, Ebola, SARS and avian flu (Suwantarat and Apisamtharat, 2015), and infection control measures may be limited during an initial encounter, at the beginning of outbreak, and if there is an overwhelming number of patient cases. Kortepeter et al. (2010) reviewed the risks to healthcare workers in developing-world clinical settings (needlestick injuries, haemorrhagic

fever viruses, severe viral respiratory disease and (multi-resistant) tuberculosis) and made suggestions for risk mitigation. They highlighted the fact that surveillance systems do not classify this group separately from business or leisure travellers but, instead, record them as tourists, missionaries or 'others'. Furthermore, this is a diverse group, ranging from short-term travellers to workers in refugee camps; consequently, their individual activities and travel destinations around the globe pose varied risks.

Recently, these diseases have also been appearing in the EU Member States, and these occurrences have been linked to changes in travel patterns and the globalisation of trade. The experts therefore indicated a need for a contingency plan. As usually no financial resources (on a national level) are reserved for exceptional conditions, such as those in which workers need to be protected from Ebola, or an outbreak of one of the recent respiratory disease pandemics, such as those linked to SARS, MERS-CoV or COVID-19, financing should be part of this plan and funds should be set aside. In health care, the financing of biological risk assessment against the risks of exceptional outbreaks is managed through central administrations, and this could cause problems.

In the expert interviews (task 2), two French experts mentioned several measures regarding the prevention of infection of healthcare workers with the Ebola virus. These included quick assessments, including an evaluation of what is needed; the development of protective clothing by a work group in contact with manufacturers; training for all kinds of professions in health care, such as nurses and doctors; and PPE guidelines. National and local cooperation between relevant stakeholders is needed. Commitment at different levels increases involvement and promotes ownership (which facilitates the implementation of the measures). Collaboration with those concerned was seen as critical to ensuring a good fit between the policy measure and the target group. Problems may arise when people are unexpectedly faced with a crisis such as the outbreak of a new infection; as a result, a variety of different initiatives may be taken. It can be difficult to coordinate and implement best practices and keep developments going. The fact that manufacturers may have an ambivalent attitude to investing in relevant developments because of the financial risk is an obstacle to progress. For pandemic influenza situations, an evaluation of protective equipment (N95 masks or surgical masks) to protect healthcare workers from influenza infection concluded that ocular protection should also be included to prevent infection through the mucous membrane of the eyes (Gralton and McLaws, 2010).

Laboratory work

Animal-related laboratory work is dealt with in Section 3.1.1 on animal-related occupations. As mentioned before, laboratory workers may be exposed to a wide range of biological agents, depending on the areas in which they work, and these are referred to in the tables of the literature review (EU-OSHA, 2019a); some of the biological agents may be in Risk Groups 3 or 4 according to Directive 2000/54/EC and may have zoonotic transmission routes. Directive 2000/54/EC has therefore set out some basic containment measures for activities that could involve exposure to biological agents. Work in clinical, veterinary and diagnostic laboratories, excluding diagnostic microbiological laboratories, is considered to at least entail possible unintended exposure to biological agents. Workplace risk assessment needs to elucidate the exact conditions and potential risks of exposure.

The experts and practitioners consulted in this study reported several successful and less successful policy measures for laboratory work that is not (directly) animal related (Annex 5, Table 16 and Table 17).

Germany has codes of practice in place to promote the application of work protection laws and directives in laboratories, for example the 'Technical Rules for Biological Agents' (Technische Regel für Biologische Arbeitsstoffe 100 — TRBA 100 'Protective measures for activities involving biological agents in laboratories' , in particular (ABAS/BAuA, 2013a). Some are provided by an accident insurance association, and the aim is to prevent respiratory or skin infections, allergies, irritations and toxic effects from pathogens. The success factors mentioned were direct feedback between the national-level authorities and health insurance experts, which promotes exchange and a joint approach; good cooperation between relevant stakeholders; and the existence of a well-established legislative framework, with the ordinance for biological agents at work (BioStoffVo) and its provisions for intentional use. In Germany, when working with biological agents, a differentiation is made between activities with and without safety level classification. This is because of different approaches to risk assessment. All activities involving the use of biological agents in laboratories, with laboratory animals, in the area of biotechnology and in healthcare facilities have to be assigned a safety level. They are therefore labelled 'safety level activities'. With safety level activities, the biological agents that occur and/or are utilised are generally known or can at least be sufficiently determined. A differentiation is also made between targeted activities and non-targeted activities. In the case of targeted activities, the safety level depends on the risk group of the biological agent to be determined. If workers carry out activities involving several biological agents, the safety level classification is determined by the biological agent with the highest risk group. In the case of non-targeted activities, the safety level classification is specified by the risk group of the biological agent that, on the basis of the likelihood of its occurrence, the type of activity, and the type, duration, level and frequency of exposure, determines the risk of infection of the workers.

Activities that do not take place in laboratories or healthcare facilities or do not involve working with laboratory animals or in the area of biotechnology are not allocated to a safety level. They are therefore called 'non-safety level activities'. These include cleaning and refurbishment work, activities in the areas of veterinary medicine, agriculture, forestry, wastewater management and general waste management, and activities in biogas plants and abattoirs. With non-safety level activities, obtaining all the necessary information for risk assessment is often difficult. This is because the range of biological agents is subject to variation and because the type, duration level or frequency of the exposure can change. The TRBA and 'Resolutions of the Committee for Biological Agents (ABAS) on requirements for activities with biological agents in special cases' reflect the state of requirements in terms of safety, occupational health, hygiene and work science with respect to activities involving the handling of biological agents. They are drawn up and adapted by ABAS in accordance with developments. Guidance is available regarding specific sectors, and some of this guidance is referred to in this report (for example the GESTIS Biological Agents Database and the TRBA).

Dutch experts reported on specific measures for the prevention of tuberculosis infection and the spread of tuberculosis from academic hospital laboratories. These include guidelines on laboratory design, gowning procedures and instructions for handling infectious materials. The facilitating factors described for this measure were workers' and employers' understanding of the seriousness of the problem, and the regular revision process of improving the measures for prevention.

Denmark has successful measures in place to prevent risks caused by genetically modified biological agents to inspectors of gene technological laboratories. The rules of these measures are very simple, and the inspectors are very well informed about how to behave because of their knowledge and awareness of the importance of the issue.

According to a French expert, the job of laboratory workers is stressful, and they may be afraid to make mistakes, making them overly cautious or too stressed to appropriately follow safety procedures, which is a hindering factor in preventing infection from biological agents in the laboratory. Moreover, the protective measures may be excessive, and the protective equipment may be uncomfortable to wear. For example, experts reported that, in France, the use of Kevlar gloves (Kevlar is a synthetic fibre strong enough to stop bullets or knives) to prevent needlestick injuries and other accidents in the lab, such as bites and cuts, has resulted in accidents. The use of Kevlar gloves reduces the workers' finger sensitivity, which is essential for performing their very delicate work. In addition, lab workers consider them an inconvenience, and they are therefore not always used.

Home care and care facilities

Home care is becoming increasingly important because of the increased average age of the population, resulting in a rise in the number of healthcare workers in outpatient care, according to the Dutch and German experts in the focus group discussions (task 3). The German experts pointed out that healthcare workers in outpatient medical care are the first to be exposed to possible outbreaks because they treat infected patients, and should therefore be included in preventive measures and receive training and information on how to deal with the risks. Outpatient clinics should be provided with financing or subsidies for implementing proper preventive measures and purchasing protective equipment and PPE. In addition to risks from needlestick injuries, exposure to specific pathogens is also an issue. Utsumi et al. (2010) investigated disease outbreaks in elderly care facilities and found that a variety of infectious agents with high median attack rates for healthcare workers were caused by *Chlamydia pneumoniae* (41 %), noroviruses (42 %) and scabies (36 %).

According to the Dutch experts, the increase in outpatient care may result in a grey area regarding who is responsible for what (for example, a caregiver may not be involved in the administration of drugs, but may help when asked to).

An intensified information programme on good hand hygiene at work is directed towards the care and welfare sector in France, specifically retirement homes, and includes measures to prevent respiratory and gastrointestinal epidemics among the elderly by increasing the hand hygiene of personnel in retirement homes. The target group is both the personnel and the residents in these homes.

In the Netherlands, national guidelines were prepared by the Infection Prevention Society to prevent infectious diseases in Dutch healthcare institutions, focusing on, for example, hospital hygiene in general

and hand disinfection. It seems that these guidelines need to be adapted and implemented in their own contexts, which can both facilitate and hinder hygiene at work.

At the stakeholder workshop, several issues were addressed regarding elderly care and childcare. A Dutch expert mentioned that elderly people are a vulnerable group in the Netherlands because of the higher retirement age. Workers in elderly care were seen as being at risk, as they have to work for a longer period because of the increasing age of the (Western) population. The experts did not indicate why this led to a higher risk; however, this could be caused by, for instance, a prolonged exposure time and older people in need of care being more susceptible to infections. Childcare was mentioned as an area of risk, because children may be exposed to more biological agents and transfer the biological agents to workers through physical contact.

The recent coronavirus pandemic has shown how the vulnerability of patients in care homes can increase the risk for healthcare workers in these facilities and put a large strain on these workers. In some countries, a very high proportion of fatalities were seen in homes for the elderly.

Dental care

In dental care settings, microorganisms can be transmitted through direct contact with contaminated instruments or surfaces, a splash or spray of infectious fluids or materials in the mucosa of the eyes or mouth, and inhalation of airborne infectious agents (Younai, 2010). The highest prevalence of hepatitis B is reported among dentists, with infection rates 3 to10 times higher than in the general population.

According to Garg et al. (2012), dental unit waterlines may be a source of infection for patients and dental workers. They therefore propose a set of hygiene measures to protect both groups. Jayanthi et al. (2013) describe the oral manifestations of prion diseases and warn of the potential, albeit low, risk to dental workers, as prion proteins resist conventional sterilisation methods used in dental clinics and laboratories.

As mentioned above and below, dental workers are also at high risk of contracting hepatitis B and at risk of developing a latex allergy from equipment and gloves.

Tuberculosis

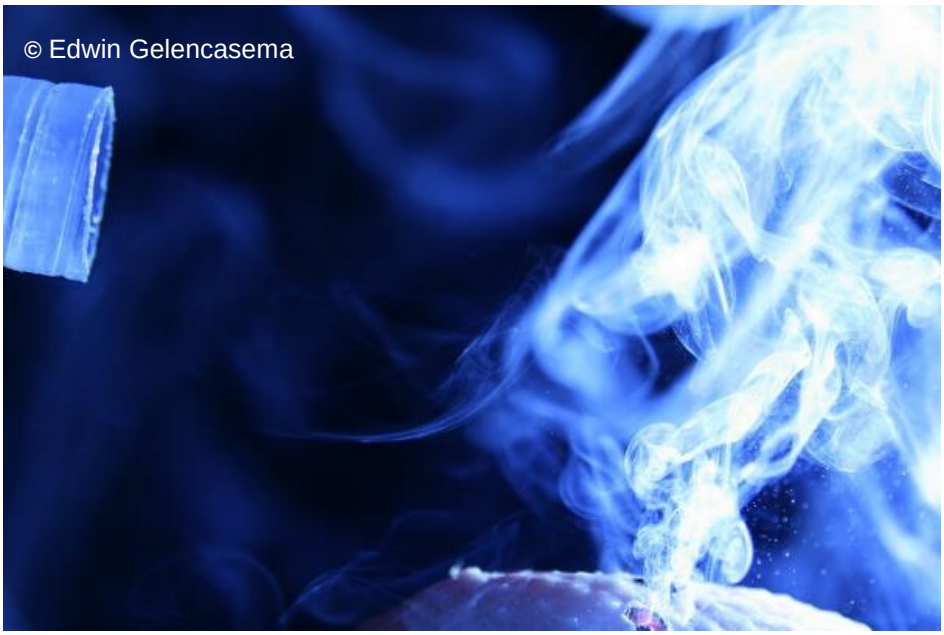
Tuberculosis is one of the best known and most studied occupational respiratory infectious diseases. Healthcare workers are a well-known risk group for tuberculosis, a disease which is mostly transmitted through the air and sometimes through needlestick injury. The likelihood of healthcare workers becoming infected with tuberculosis is estimated to be twice that of the general public in high-income countries, and up to 10 times that of the general public in low-/middle-income countries. There is concern that healthcare workers could be exposed to potentially viable *Mycobacteria tuberculosis* in surgical smoke ([18]). Seidler et al. (2005) found the risk of tuberculosis to be elevated in hospital workers in wards

([18]) Surgical smoke plume is a dangerous by-product, a gaseous material generated from the use of lasers, electro-surgical pencils, ultrasonic devices and other surgical energy-based devices. As these instruments cauterise vessels and destroy (vaporise) tissue, fluid and blood, a gaseous material known as surgical smoke plume is created. It is estimated that approximately 95 % of all surgical procedures produce some degree of surgical plume.

with tuberculosis patients; nurses in hospitals; nurses attending HIV-positive or drug-addicted patients; pathology and laboratory workers; respiratory therapists and physiotherapists; physicians in internal medicine, anaesthesia, surgery and psychiatry; non-medical hospital personnel in housekeeping and transport work; funeral home workers; and prison workers. The development of tuberculosis in an exposed individual is a two-stage process following infection. In most infected persons, infection is contained by the immune system and bacteria become walled off in caseous granulomas, or tubercles. In about 5 % of infected cases, rapid progression to tuberculosis will occur within the first 2 years after infection (Narasimhan et al., 2013), but the risk of progression is much higher, at about 10 % of infected cases within the first year, in HIV-positive and other immunocompromised individuals.

Surgical smoke

In the literature review, a significant amount of publications on the risk of surgical smoke was retrieved. Bioaerosols may be produced in surgical smoke generated at low temperatures, for example when using harmonic scissors, and this smoke may contain live multidrug-resistant *Mycobacterium tuberculosis* or viral DNA of the hepatitis B virus, hepatitis C virus, HIV or human papillomavirus. The risk of transmission of an infectious disease if bacterial or viral fragments are inhaled via surgical smoke, owing to the use of ultrasonic scissors, lasers and electrocautery, is alarming, although evidence of pathogen transmission via surgical smoke is reportedly inconsistent. No epidemiological studies have been conducted on bacterial transfer via surgical smoke. However, virological analyses have confirmed or suggested a causative link between occupational exposure to human papillomavirus DNA and the laser plume generated by medical lasers, as well as the occurrence of laryngeal papillomatosis.



However, none of the prevention programmes identified in the interviews or discussions in the focus groups touched on the topic of surgical smoke.

Vulnerable groups

The experts mentioned vulnerable groups in health care in general: cleaners, (medical) students (as they are less experienced), individuals with chronic diseases or treated with immunosuppressants, and healthcare workers who are travelling for work or have contact with travellers who may have been exposed to organisms of an unknown nature. Carers in home situations, cleaners in hospitals and workers who sterilise medical equipment may be exposed to infections from needlestick injuries, cuts or spills.

The experts in the focus groups thoroughly discussed cleaners as a vulnerable group, since they often perform tasks with potential unknown exposures and the risk of needlestick injuries. In addition, there

may be differences between internal and external cleaning services; for instance, the persons responsible for providing information about risks and safety measures, the provision of PPE and the vaccination of personnel may be different. Furthermore, the quality of the tools that are used for cleaning and how to make sure that everyone adopts the right measures were also discussed.

Nurses in training, medical trainees or young healthcare workers are reported to be a vulnerable group at risk of contracting serious diseases such as Hepatitis Band C, measles, HIV and other locally endemic diseases such as malaria, dengue fever, traveller's diarrhoea and sexually transmissible infections, as well as nosocomial transmission of blood- or body fluid-borne pathogens, when they work abroad.

Rescue workers

In 'healthy' buildings, the indoor airborne fungi composition is similar to that of the outdoor fungi.

However, certain circumstances may result in optimal conditions for fungal growth, resulting in a composition of fungi in buildings that could lead to ill health. For instance, in the aftermath of a natural disaster such as a tornado or flood, moulds have optimal conditions for growth. Rescue workers and medical personnel who are required to work under these conditions are at particular risk of an allergic response, and protective measures should be taken (Johanning et al., 2014).

3.1.3 Waste and wastewater treatment

The waste and wastewater management sector, as considered in this project, encompasses a wide range of occupations (e.g. waste collectors, waste handlers, waste-composting workers, sewage workers, sewage treatment plant workers). An extensive overview of specific biological agents and related health problems for this group of workers is provided in the literature review, and referred to in the literature search, the expert survey, the data from selected monitoring systems and a dedicated article (EU-OSHA, 2019d). The literature review highlighted the following infectious diseases in the waste and wastewater treatment sectors: respiratory symptoms such as bronchitis, gastrointestinal symptoms such as diarrhoea and nausea, hepatitis (A, B, and C), HIV, syphilis and hepatitis E infections. These diseases are often due to sharps and needlestick injuries and exposure to bioaerosols. The microorganisms referred to in the review are, for example, *Brucella* spp., *Campylobacter* spp., *Escherichia coli*, *Legionella* spp., *Mycobacterium tuberculosis*, *Salmonella* spp. *Staphylococcus aureus*, *Toxoplasma gondii*, hepatitis virus A, B and C, and HIV. Spain reported a Q fever cluster in waste processers in the questionnaire survey.

There is also an increasing awareness of fungi as a cause of disease in newer occupations such as jobs in waste management; however, this awareness does not yet seem to be reflected in reporting and recognition practices. Increased exposure to endotoxins, mycotoxins, beta-glucans (via organic dust) and bioaerosols is related to, for instance, adverse respiratory effects, irritation of the sense organs (e.g. skin, eyes) and increased immune system activity (Anzivino-Viricel et al., 2012). The microorganisms

linked to these effects are *Acinetobacter* and *Thermoactinomyces* (both causing hypersensitivity pneumonitis), which are related to respiratory problems, the fungi of the species *Alternaria*, *Aspergillus, Cladosporium, Cryptococcus, Geotrichum, Penicillium, Rhodothorula* and *Trichoderma* and endotoxins, as well as exotoxins such as aflatoxin and ochratoxin.

Below, the results of the expert interviews, focus group discussions and stakeholder workshop, as well as results from the literature review, are described for this sector.

A combination of several risks

Workers in the sector are exposed to a variety of risks. This wide range makes it difficult for employers and occupational physicians to select the best means of prevention for this group. The experts explained that it is very difficult to pinpoint the precise risks that workers are exposed to (for example sewage workers). Interestingly, when discussing risks and measures for waste treatment, both the Dutch and the French experts explained that preventive measures tend to focus on one specific problem, instead of a combination. The French experts even considered that measures targeting a specific risk too strongly were dangerous. They argued that a more generic approach would include protection from different risks altogether. The French experts commented that prevention methods in the waste treatment sector should not be targeted too rigidly, as, in practice, workers are exposed to a mixture of chemical, biological and physical risks. Ideally, a measure should protect against all risks; for example, gloves should protect workers from biological, chemical and mechanical risks.

Experts from France and the Netherlands recommended that additional research be carried out on prevention, to discover the specific biological agents that workers are exposed to and to determine the health-related effects of long-term exposure. A better understanding and greater awareness of biological risks are vital for a detailed evaluation of the health effects of combined exposures.

At the company level, the use of PPE is monitored to improve knowledge and risk awareness and motivate workers to use PPE, which traditionally is the last preferred option to prevent workers from exposure. The French experts called it a lack of a prevention culture, which led to several problems for workers: (1) workers did not have to use PPE; (2) workers had to use the same PPE for the entire week; (3) workers had no changing room or facilities for washing before eating. The experts recommended better information and training on the occupational risk of exposure to biological agents.

Below, the results from the literature review and the expert interviews and focus group discussions are described for each subsector (composting and waste handling, recycling, and sewage and wastewater management).

Emerging issues

The experts were more divided in their perception of emerging risks in waste treatment than in the other sectors discussed. The high-priority emerging risks in waste treatment, according to the experts in the focus group discussions, are (1) exposure to a combination of risks and bacteria due to increased collection and separation of organic waste, (2) biomass-related allergens and (3) accidental exposure to fungi due to increased collection and separation of organic waste. The Dutch experts were mostly concerned about the risk of blood-borne viruses from accidents with sharp objects during waste handling. Only the Dutch and German experts listed allergens in their top three high-risk biological agent categories. The Dutch experts added multi-exposure related to waste collection to this list. Experts from France added pathogenic toxins to their list.

In waste management, workers' exposure is very complex and depends on many factors, as already explained. Many trends in industrial developments are linked to environmental legislation or in a wider context may influence workers' safety and health. Waste management and composting, which are growing sectors, are associated with exposure to specific allergens. The Danish experts saw an increase in recycling activities, leading to more handling of waste. The Dutch experts added that the decreasing frequency of waste collection gave microorganisms the opportunity to grow in waste, which could increase the exposure of waste collectors. There is a shift from storing waste in plastic garbage bags towards storing it in larger plastic containers (with, for instance, separate containers for plastics, biodegradable waste and residual waste). Therefore, municipalities can collect waste less frequently than before (for instance once every 2 weeks, instead of weekly). Although this is considered an improvement, since garbage collectors are less likely to have accidents with sharp objects and be at risk of exposure when bags are torn, it does increase the risk of exposure of workers who are collecting and handling the waste, because the circumstances in these containers are generally optimal for the growth of microorganisms, and they are given more time to grow.

The French experts provided an example of how climate change (bacteria grow more quickly at warmer temperatures) and an increase in recreational activities can increase the occurrence of a disease, in this case leptospirosis, transferred from rats to humans, which is already a problem in several major cities.

EU-OSHA has identified as potential emerging risks the biohazards linked to work with new bacteria developed in bioengineering, and increased exposure to bacteria and fungi due to increased collection and separation of organic waste (EU-OSHA, 2013). The expected increase in green jobs ([19]) in the future may result in more workers becoming sensitised to biomass-related allergens.

Composting and waste handling

A relatively large number of publications was retrieved on waste workers (waste collectors, waste-composting workers, waste handlers and related occupations). Kuijer and Sluiter (2010) reviewed health outcomes in waste collectors and found that strong evidence was available that exposure to bioaerosols exceeds recommendations. Increased exposures to endotoxins, mycotoxins (Fromme et al., 2016), beta-glucans (via organic dust) and bioaerosols were related to various adverse health outcomes including respiratory inflammatory reactions, ODTS, high fever, eye, nose and throat irritation, coughing, itching, a reduction in lung function (one-second forced expiratory volume (FEV1)), an increase in the prevalence of atopy and myeloperoxidase production (an indicator of immune system activity).

([19]) Green jobs cover a wide range of different jobs in different sectors and involve a diverse workforce. There are many different definitions of the term, such as the ones by the United Nations Environment Programme, the European Commission and Eurostat. Nevertheless, green jobs can be understood as contributing, in some way, to the preservation or restoration of the environment. They can include jobs that help to protect ecosystems and biodiversity, and jobs that reduce the consumption of energy and raw materials, waste and pollution.

This matches the assessment by the experts in the focus groups, who agreed that the current risks in waste-handling and waste-sorting centres are organic dust and specific bacteria and viruses. Much of their recommendations were targeted at the waste treatment sector in general.

As the literature shows, exposure to organic dust in composting facility workplaces is associated with several adverse effects on the respiratory system. The pattern of health effects differs from those found in other workplaces with exposure to organic dust, possibly because of the high concentrations of thermo-tolerant/thermophilic actinomycetes and filamentous fungi in composting plants. The bioaerosol components identified in a review by Pearson et al. (2015) as potentially harmful are as follows:

- fungi and fungal spores — including the thermotolerant species *Aspergillus fumigatus*;
- bacteria — including Gram-negative bacteria and the spore-producing Gram-positive bacteria actinomycetes;
- endotoxins — structural components of some bacteria released through cell wall damage, including lipopolysaccharides or lipooligosaccharides;
- dust or particulate matter containing microbial fragments;
- Beta(1→3)-glucans — polysaccharides found in the cell walls of certain fungi, particularly *Aspergillus* species;
- mycotoxins — toxic secondary metabolites of fungi (one of the most potent of these is aflatoxin, which is mainly produced by *Aspergillus flavus*), which may also be emitted during the composting process

Depending on particle size, bioaerosols may penetrate deep into the lungs and become embedded in alveoli. For bioaerosols emitted from composting facilities, the following health effects have been identified:

- allergic asthma, rhinitis, hypersensitivity pneumonitis or extrinsic allergic alveolitis, allergic bronchopulmonary aspergillosis, eye and skin irritations;
- toxic non-allergic asthma, rhinitis, mucous membrane irritations, chronic bronchitis, chronic airway obstruction such as COPD, ODTS, toxic pneumonitis;
- infectious aspergillosis, zygomycosis.

Immunocompromised individuals are more susceptible to lower concentrations of the relevant pathogens.

Practitioners from four countries agreed in the focus groups that exposure to organic dust was an important issue. The Dutch experts talked about green waste/compost containing allergens, and the French talked about handling organic waste. The Danish experts explained that the concentrations of organic dust in waste treatment are not as high as those in agriculture. However, the composition may be more diverse, and this results in 'more active' dust than normal dust. Some of the points raised by the experts are as follows:

- According to the French experts, the workers in waste-sorting centres, which are humid and warm environments, are exposed to a wide variety of risks. Not all possible routes through which biological agents can enter the body are covered by adequate preventive measures.
- During the stakeholder workshop, it was stated that, in the waste sector, companies lack a proper approach to performing risk assessment. However, waste handling is licensed and strictly monitored in some countries, such as Finland, and waste treatment plants must carry out a thorough Environmental Impact Assessment, including a risk assessment of the work environment.
- The risk of dermal exposure in the waste treatment sector was stressed by a workshop participant from Portugal, who mentioned that fungi are an important issue because workers do not wear gloves to protect themselves, and fungi might therefore become trapped under the fingernails, resulting in possible exposure at a later point, for example while eating.
- The experts from both France and the Netherlands stressed that technological solutions are not particularly suitable for waste treatment facilities and that investments and/or ventilation systems that are designed for this specific purpose are needed to improve the air quality in waste treatment plants.
- It was advised that technological solutions separating workers from waste entirely should be developed, or solutions designed specifically to suit this sector (such as ventilation systems).
- Because workers in waste handling are often temporary personnel hired through agencies, not everyone is included in companies' vaccination programmes (as this is the responsibility of the agency for which they work).
- Another discussion addressed the location of the risk within the waste treatment sector, i.e. in open spaces or contained spaces. Waste is often treated in open spaces in which aerosols are present and it is difficult to contain biological agents, whereas in waste treatment facilities the waste treatment process is often much more contained and hence more controllable. Therefore, the focus in the waste treatment sector should be on open spaces. However, one of the experts mentioned that exposure to, for instance, moulds in a closed environment is very likely to occur.
- A Finnish expert (HSE manager in a waste-sorting plant) explained that bacteria and viruses in biological waste such as hospital waste are the greatest risk, and that, although waste processing easily destroys bacteria, the destruction of viruses is more difficult. This expert advised that work processes should be adapted to ensure that viruses are destroyed and workers are not exposed.

However, it seems to be increasingly recognised that action needs to be taken on these issues:

- Finnish experts reported that, on the EU level, new guidance is being developed for best practices in waste management.
- In Finland, when making plans and applying for permits for a new installation, both the inspector and those processing the permit applications must know the best practices in the field and choose the best solutions.
- The German experts did not expect a strong increase in risks in this sector, as they concluded that the sorting of waste is mainly automated and that the process of collecting waste will stay the same. However, they still deemed it necessary to improve monitoring and inspection on the national level, by improving legislation and the control of plants and their operations.

- In the Netherlands, as in Finland, the processing of compost is increasingly performed by means of processes in closed systems, which means workers are separated from the waste and thus from the risk of exposure to allergens. A Dutch expert also mentioned that many attempts had been made to improve the air quality in waste-sorting cabins, including improving ventilation and airstreams, but these were still not effective enough, and workers still had to wear respiratory equipment.
- On the topic of handling organic waste, the French experts recommended separating activities in waste treatment plants to prevent exposure between different waste flows in the waste treatment chain and improving ventilation to reduce dust concentrations, and thus the concentration of biological agents, in the air. However, as the Dutch experts explained, to avoid exposure to these allergens during the **collecting or handling** of green waste, workers should wear breathing masks, which they consider difficult for long periods of time.
- The Finnish, French and Dutch experts also talked about developing technological solutions to separate workers from waste entirely, to reduce the risk of exposure to biological agents. In Finland, new waste treatment plants have closed systems for waste processing. In the Netherlands, green waste is already processed in closed systems. These good practices could be shared across EU Member States to improve the overall protection of workers in what is one of the fastest growing economic sectors in Europe.
- A lot of research has been conducted in this sector in Germany and it was mentioned in the literature review. Some of the exposure studies conducted by BAuA (see Section 5.4.1 of the literature review) provide valuable information on exposure to biological agents in waste workers. The studies cover composting, waste recycling and waste incineration. Cases of diseases in the waste management sector were also identified through alert systems in France and in the Netherlands (EU-OSHA, 2019a). The German GESTIS Biological Agents Database (DGUV, 2017) and the German TRBA provide information and guidance for workplace prevention (for example ABAS/BAuA, 2013a). The GESTIS activity datasheets provide information on biological agents that may arise during these activities, their routes of transmission and possible risks, and they list the technical, organisational and personal protective measures to be taken. In addition to references to the relevant rules and regulations, there are also links to operational instructions for practitioners in various sectors and activities that need to be adapted in individual companies, following workplace risk assessment. Both were presented as examples of national policies in the stakeholder seminar (task 4). The ‘Guideline for risk assessment and for the instruction of workers regarding activities with biological agents’ (TRBA 400) (ABAS/BAuA, 2017) introduces a convention on sensitising and toxic hazards that follows a control-banding approach. It is based on an exposure matrix that links information on assumed/estimated exposure levels (without measuring) to the estimated risk that must be controlled. Exposure matrices for moulds and endotoxins in different occupations are also available and some examples were shown during the stakeholder workshop. TRBA/TRGS10 406 ‘Substances causing airway sensitisation’ sets out prevention measures for sensitisers originating from moulds (for example *Aspergillus* spp.). TRBA 220 sets out rules for workplace prevention in sewage plants (ABAS/BAuA, 2010a). The workshop report and presentations are available online and can be consulted for further details (EU-OSHA, 2018a).
- The German Institute for Occupational Safety and Health of the Social Accident Insurance Institutions (Institut für Arbeitsschutz, IFA) and the Dutch authorities have developed measurement methods to allow better identification of exposures and establish a better link between causal factors and disease, especially in cases of hypersensitivity reaction. Furthermore, Germany has set a technical control value for spores of mesophilic moulds in the workplace air of waste-handling facilities (5×10^4 spores per m^3 respiratory air, TRBA 214; ABAS/BAuA, 2018). To date, no other technical control values exist. The Biological Agents Unit of the Statutory Accident Insurance Association (DGUV) has analysed the data in the

MEGA ([20]) database for concentrations of moulds and endotoxins in workplaces. An extract of this analysis is expected to be published in TRBA 400 on risk assessment, which is being adapted.

Accidents with sharps

In the focus groups, the Dutch experts talked about accidents with sharp objects during waste handling causing risks of infection with **blood-borne viruses**. These accidents happen during the separation of waste or when garbage is collected, especially when garbage bags are used (which tear easily) instead of containers. Not only needles but also glass and cans are separated by hand. Where this waste originates from is mostly unknown.

For this risk, the Dutch recommended many additional measures, such as technological innovations (robots) to separate workers from the waste, as in green waste processing; vaccinating workers; using PPE and monitoring PPE usage in companies in a uniform way; and awareness-raising and information on safely disposing of needles for patients who use needles at home.

The Dutch experts explained that the process of prohibition (not allowing certain types of waste in residential waste or stricter rules for the separation of consumer waste by consumers) is effective only in the long run, because sources of waste are often unknown and people still have certain types of waste at home. Therefore, solutions should focus more on technological measures (direct protection for workers) and less on regulation.

Recycling

In general, on the topic of recycling resulting in more handling of waste, the Danish experts considered it important to create **more precise rules** to protect workers who handle the waste.

An interviewed Danish expert mentioned a less successful initiative concerning recycling workers that included rules and guidelines on how to work in a recycling facility, including prohibiting use of high-pressure water for cleaning, as this increases infection risks for recycling workers. Two factors hindered the implementation of the measures in the recycling industry: the attitudes of both management and the

([20]) Messdaten zur Exposition gegenüber Gefahrstoffen am Arbeitsplatz (Data on Exposure to Hazardous Agents in the Workplace) — the MEGA database — is a compilation of data gathered through atmospheric measurements and material analyses. Data on hazardous chemicals have been compiled in the database since 1972. Since 1998, the documentation has included data on biological agents in the workplace.

workers in the recycling facility (who were sceptical about the problem) and their low level of education. According to the expert, few of the workers believed or understood that there was a serious structural risk connected to working in recycling. This resulted in them not using the guidelines properly and continuing to become ill. Even simple measures may not be so easy to implement in this sector. A review of established European practice in relation to biohazards associated with waste and waste-related biofuels carried out by Swords (2011) found that, although in general the relevant control measures to prevent exposure are known (and can be related to relatively simple hygiene and housekeeping, such as the avoidance of power-hosing to clean surfaces in order to prevent the formation of aerosols), the implementation of these control measures has to be engineered on a step-by-step basis to reduce exposure pathways (e.g. a change in equipment surfaces may be needed to facilitate alternative cleaning methods). However, the skills necessary for this may not exist within many companies already engaged in the waste sector, and for a gap analysis of their needs they may need to turn to specialists with the necessary experience gained in the process industries.

Sewage and wastewater

Sewage and unstable sludge contain various pathogens such as viruses, bacteria, and human and animal parasites. These microorganisms can be transmitted to the ambient air in wastewater droplets, which are generated during aeration or the mechanical moving of the sewage. Bioaerosols generated during wastewater treatment may therefore pose a potential health hazard to workers at these plants.

Leptospirosis (from infection with *Leptospira* spp.) was reported among wastewater and sewage workers. In France, leptospirosis is sometimes commonly known as ‘sewage worker’s disease’ (*maladie des égoutiers*), as these workers are directly exposed to rats and water contaminated with rats’ urine. This is also an issue in agriculture, as referred to in Section 3.1.1. In addition, wastewater workers may be at risk of contracting legionellosis. Sewage workers are also among the groups of workers with known risk of hepatitis E infection. Archaea as immunogenic agents in bioaerosols in agriculture and wastewater treatment plants may also be an emerging risk, although the role of archaea in the aetiology of respiratory illnesses is not clear (Blais Lecours et al., 2014).


Dragan LEKIC/Libre arbitre

Allergenic agents are considered a clear risk in wastewater treatment plants. A causal relationship between exposure to non-infectious airborne biohazards and the occurrence of gastrointestinal symptoms, fever, respiratory symptoms, skin disorders, eye irritation, headache, fatigue and nausea among the workers of sewage treatment plants was also reported (Korzeniewska, 2011). Fungi-related hypersensitivity pneumonitis and asthma are reported for a broad spectrum of indoor occupations, including sewage workers.

Preventive measures

An expert from Denmark described successful measures to prevent gastrointestinal problems among sewage workers in the Copenhagen municipality (Annex 5, Table 11 and Table 12). The measures

included sewage-handling guidelines, avoiding high-pressure water cleaning and vaccination rules against hepatitis and tetanus. The measures, commissioned by the municipality (basis of support) of Copenhagen, meaning that the project had support at this level from the start, were designed to be a good fit for a local problem. Incidence measurements offered clear evidence of the effectiveness of this policy, and the evidence could be used to develop relevant guidelines regarding vaccinations. The expert explained that it was very important to have data that clearly showed that high-pressure water cleaning in sewage systems increased the risk of infection among sewage workers and should therefore no longer be used.

A French expert mentioned a programme by the sectoral social security organisation — Agricultural Social Security Scheme (Mutualité Sociale Agricole, MSA) — that is targeted at drainage workers and wastewater treatment plant workers who work outside. It included training and information for workers and vaccination to prevent infection from leptospirosis via contaminated water. People's willingness for a vaccination resulted in an increased vaccination rate and better prevention. However, it was also mentioned that it remains difficult to prove the necessity of the programme, as the risk of exposure is not always clear, and it is deemed unnecessary by the workers. Workers are willing to get vaccinations, but the immunisation is not as effective as expected and needs to be regularly refreshed, while the positive effects are also difficult to trace because there are not enough data on situations in which exposure is probable.

3.1.4 Occupations that involve travelling or contact with travellers

Workers in occupations that involve travelling or contact with travellers (with the exception of healthcare workers) are increasingly at risk because of the changing patterns in travelling behaviour and global trade. An overview over the biological agents that these occupations may be at risk from is provided in the literature review and a related discussion paper (EU-OSHA 2019a, 2019f). Of particular concern in relation to vulnerable people is hepatitis E, which is believed to be associated with travelling to endemic areas. The types of workers at risk of contracting similar diseases to those of leisure and business travellers are transport staff and workers at borders (e.g. airline personnel, customs workers), global trade workers, workers in war zones, epidemic control (field) workers, epidemiologists, journalists and media professionals. The diseases associated with infection risks to these workers are avian flu, Q fever, dengue fever, Ebola/Marburg virus infection, tularaemia, *Legionella*, measles, tuberculosis, yellow fever, SARS, cholera and meningitis.

During the stakeholder workshop, participants agreed that workers in these occupations were at risk because individuals might differ considerably in their level of immunity. For example, a Western worker who travels to Africa may lack specific immune proteins that protect against the biological agents that

are endemic in Africa. More specifically, truck drivers in Lithuania were mentioned to be at higher risk of pre-occupational malaria than other workers.

3.1.5 Other occupations and other biological agents

The literature search also resulted in information on other occupations with a risk of exposure to biological agents. However, there was a paucity of literature on occupations in the aquaculture sector, bone button makers, border guards, fertiliser workers and outdoor game managers (i.e. individuals who are responsible for the protection of wild animals that are hunted for sport). Hunters were also identified as a group at risk of hepatitis E virus infection. Outdoor workers in general were mentioned because they may face new risks (new microorganisms) as a result of a wider spread of microorganisms because of climate change, for example the West Nile virus, which is occurring in Italy. Those specifically mentioned were public garden workers and road maintenance workers.

Other relevant sectors were mentioned at the stakeholder workshop (EU-OSHA, 2018a). The participants identified people working with refugees/the homeless as a group of workers at a higher risk of exposure to biological agents, as these people might carry and transfer foreign biological agents. In the Netherlands, the potential additional risk of biological agents when working with refugees is currently controlled by the performance of specific risk assessments.

In addition, prison workers/guards were mentioned as a high-risk group because of the risk of infection with tuberculosis and measles; this was confirmed by the literature review (Seidler et al., 2005), and in the stakeholder survey and the data collection from national monitoring systems. Regardless of a control system, outbreaks occasionally occur in this group of workers.

Legionella

It is generally accepted that working areas with air-conditioning systems, high humidity or systems containing stagnant warm water are amenable to the growth of *Legionella*. Workers at risk are automotive plant workers, workers in places where mist machines are present, construction workers, plumbers, water system workers, biological treatment plant workers and wastewater treatment workers, those in cleaning and disinfection jobs in contaminated areas, cooling tower workers, air-conditioning maintenance workers, professional (bus) drivers (Pontiac fever), forest workers, gardeners, healthcare workers, journalists, laboratory personnel, ship repair workers, mine workers, offshore workers, paper mill workers, pet shop workers, plant and machine operators/assemblers, plastic factory workers, print plant workers, railway conductors, sewage workers, subway personnel, textile plant workers, turbine operators, vehicle washers, welders, workers in war zones and zoo personnel. Risk systems for *Legionella* exposure include water systems incorporating a cooling tower, water systems incorporating an evaporative condenser, hot and cold water systems, spa pools (also known as whirlpool baths, hot tubs and spa baths), humidifiers and water misting systems, waterlines to dental chairs, aeration ponds in biological treatment plants and industrial wastewater treatment plants, high-pressure water cleaning machines, and other plants and systems containing water that is likely to exceed 20 °C in temperature and may release a spray or aerosol. Cleaning and maintenance of the aforementioned systems is associated with a risk of exposure to *Legionella*. During the stakeholder workshop, participants discussed how *Legionella* in cooling fluids related to the metalworking sector is considered to be a problem in Portugal.

The risks from exposure to *Legionella* are normally controlled by measures that prevent the proliferation of the bacteria in the system, and by reducing exposure to water droplets and aerosols (EU-OSHA, 2011). Precautions include:

- controlling the release of water sprays;
- avoiding water temperatures between 20 °C and 45 °C;
- avoiding water stagnation that can encourage the growth of biofilm;
- avoiding the use of materials that harbour bacteria and other microorganisms or provide nutrients for microbial growth;
- maintaining cleanliness of the system and the water in it.

As a last resort, maintenance personnel might need to use personal protection equipment (such as respirators).

Sex workers

Owing to the nature of their occupation, sex workers are at risk of sexually transmissible infections (STIs), among which the most serious are the causative agents of syphilis, gonorrhoea, herpes and trichomoniasis, and exposure to HIV, hepatitis B and C viruses, and *Chlamydia*. Europe has a low endemicity of HIV, whereas Africa and Asia are highly endemic areas.

Most publications retrieved regarding sex workers are related to HIV infections, and half of these are of only limited relevance, as they concern regions or countries outside Europe. STIs are of significant relevance to sex workers, although HIV is considered the major focus, possibly because of the fatal outcome and long-term effect on quality of life.

The HIV infection rate in Europe is low among female sex workers who do not inject drugs (< 1 %), but for other STIs the infection rate is high, particularly for syphilis and gonorrhoea. With regard to the prevention of STIs among sex workers, prevention programmes are reported to be not always effective. Female sex workers experience high levels of violence and lack access to services, and they often work on the street (Platt et al., 2013; Shannon et al., 2015). Findings show that, for prevention programmes aimed at reducing STIs among sex workers to be effective, interventions should be embedded in strategies that address the social welfare of sex workers and experiences of violence and migration, and provide access to services or social support and antiretroviral therapy. The related literature recommends that epidemiological and intervention studies of HIV among vulnerable groups such as sex workers take more systematic account of how all these factors combine to increase or reduce the risk of HIV/STIs. Furthermore, according to Wilson (2015), HIV and STI prevention programmes aimed at sex workers receive limited domestic financing in many countries and have not evolved adequately to address informal sex workers, male and transgender sex workers, and mobile and internet-based sex workers, and some experts recommend shifting funding allocations towards priority populations, as this is more cost-effective than targeting the general population.

3.2 Allergenic and toxic agents

According to the EU directive on biological agents, in their workplace risk assessment employers have to consider potential allergenic or toxigenic effects as a result of work. The identification of allergens linked to exposure to biological agents and their differentiation from chemical agents is the most challenging issue identified in this review — although it is the most researched issue — as the exact cause of the allergy at the agent level cannot easily be identified. Except for farmer's lung, it is rather difficult to distinguish biological allergens and the diseases related to them. The sectors and occupations in which there is a clear risk include the agricultural and fishery sectors, the food industry, the woodworking and metalworking industries, and waste treatment, composting and waste collection. Some of the issues specific to allergens in these occupations were included in Section 3.1 of this report. For many occupations, however, the exact agent or substance causing the allergic reaction is not yet known. In these areas, the risk is often not limited to one biological agent but relates to a number of different agents and a range of possible triggers, further increasing the risk of disease. Occupational asthma in farmers and farmer's lung — hypersensitivity pneumonitis — are also the conditions most frequently reported in the literature. These are followed by allergies triggered by laboratory animals, allergies resulting from working with wood and allergies due to bacterial or fungal contamination of metalworking fluid in the metalworking industry. Agriculture, food preparation, food management, fishing and aquaculture are associated with allergens originating from plants and animals, as well as co-existing allergenic sources such as bacteria, fungi and insects. Apart from fungi in buildings and farming, some work has been done within wood industry-related workplaces, in the forestry and sawmilling sectors, but on the whole it is rare for fungal allergens to be measured in other occupational settings (Prester, 2011). Nevertheless, it was reported that, for bakers, in addition to flour, other allergen sources including fungal enzymes and moulds should be considered (Quirce and Bernstein, 2011; Quirce and Diaz-Perales, 2013). Moreover, Zacharisen and Fink (2011) reported occupational hypersensitivity pneumonitis in the food industry, among workers dealing with dry sausage moulds (sausage/salami makers), mouldy

cheese (cheese makers), mouldy brewing malt (mill workers and malt workers) and soy sauce production processes (soy sauce brewing workers).

In the literature on allergenic agents, a differentiation between chemical agent and biological agent is not normally applied, although there are cases in which a link between a substance originating from microorganisms and allergenic effects is elucidated. Studies by Quirce and Bernstein (2011) and Zacharisen and Fink (2011), for example, included allergens originating from certain bacteria, fungi, insects and insect stings related to an occupation. The literature covers a range of allergens (e.g. microorganisms and allergens originating from plants, animals, insects and even foodstuffs), irrespective of whether or not they are biological agents in the narrow sense of the term. This is one of the reasons why a broader definition of biological agents was applied and a wider range of possible sources of allergens considered in this review. For the purpose of this report, biological agents as defined in Directive 2000/54/EC, antigens of plant and animal origin and substances produced by microorganisms were included among the occupational allergens targeted by the research. Tables 20-24 of the literature review (EU-OSHA, 2019a) provide an overview, based on the literature, of occupations and related diseases and allergens, grouped by agent category. They summarise the information extracted from the publications that were considered relevant.

Some of the relevant issues, such as exposure to organic dust and related diseases such as farmer´s lung, have already been discussed in the chapters related to agriculture and animal-related occupations. Other issues highlighted in the literature review and addressed by the experts are described below.

ABAS and the German Committee on Hazardous Substances (Ausschuß für Gefahrstoffe — AGS) have developed a joint code of practice on sensitising substances (TRBA/Technical Rules for Hazardous Substances — TRGS — 406), which outlines obligations of employers. It covers many of the issues addressed in this section, makes reference to sensitising agents from both biological (originating from fungi, bacteria and some parasites) and chemical origin, and provides details on workplace risk assessment, prevention measures and other obligations, such as the protection of vulnerable groups. This joint approach to prevention highlights the issues mentioned above, namely that in practice a distinction between allergenic agents with a biological origin and from chemicals is difficult, and

sensitising agents should really be covered by a set of prevention measures that address both origins (ABAS/BAuA, 2008). ABAS and AGS also cooperate on other issues, such as provisions for health surveillance linked to both areas of exposure (Förster, 2017; EU-OSHA, 2018a).

In addition to allergenic effects, exposure to toxins is covered in this section of the report. As mentioned above, in addition to living (micro)organisms (e.g. bacteria, viruses, fungi, yeasts and prions), substances or structures that originate from living or dead organisms (e.g. exotoxins ([21]), endotoxins ([22]), glucans and mycotoxins) were included in the review and are described in Section 3.2.4.

The classification list (Annex III) included in the EU directive on biological agents also includes notations of microorganisms that may produce toxins, mainly exotoxins, such as those produced by *Bacillus anthracis*, *Bordetella pertussis*, *Clostridium botulinum/difficile/perfringens/tetani*, *Corynebacterium diphtheriae/pseudotuberculosis/ulcerans*, *E. coli*, verocytotoxigenic strains (e.g. O157:H7 or O103), *Pseudomonas aeruginosa*, *Shigella dysenteriae* (type 1), *Staphylococcus aureus*, *Streptococcus pneumonia/pyogenes* and *Vibrio cholerae* (including El Tor). Equally, notations for allergenic effects are included, for example, for the parasites *Anisakis simplex*, *Ascaris lumbricoides*, and *Ascaris suum*, and the fungi *Aspergillus flavus/fumigatus*, *Candida albicans*, *Coccidioides immitis/posadasii*, *Cryptococcus gattii* (*Filobasidiella neoformans* var. *bacillispora*), *Cryptococcus neoformans* (*Filobasidiella neoformans* var. *neoformans*), *Epidermophyton floccosum*, *Microsporum* spp., *Paracoccidioides brasiliensis*, *Talaromyces marneffei (Penicillium marneffei)* and *Trichophyton rubrum/tonsurans*.

Exposure limits or guidance levels for allergens and toxins

As far as is known, currently only a limited number of limit or reference values for allergens and toxins related to biological agents are available. They are referred to in the sections below and have been defined for flour and grain dust, endotoxins, mould spores and selected enzymes. However, as the levels of, for example, endotoxins are not related to dust levels, specific prevention measures would need to be established for all the risk factors, i.e. dust-preventing measures, mould growth prevention and the prevention of the growth of endotoxin-generating bacteria. Other measures should be established to prevent allergies to rodents, mites or insects or the aggravation of allergies.

3.2.1 Fungi and allergies

Although fungi can be infectious and toxic, inhalation of fungi is more commonly associated with sensitisation and allergic diseases. Fungal allergy can manifest in various ways, for example asthma, rhinitis, conjunctivitis, urticaria and atopic dermatitis. Fungal allergens have been investigated systematically only in relation to *Aspergillus fumigatus*, *Alternaria alternata* and *Cladosporium herbarum*. Not much is known about the allergens, although it is known that many fungi have homologous allergens, and cross-reactivity is common. Owing to this high cross-reactivity, very few species-specific allergens have been identified. In addition, there is little information on fungal allergens in occupational environments other than agriculture.

β-1,3-glucanase has been identified as a general fungal allergen (Dutkiewicz et al., 2011), but this is not a protein exclusive to fungi, as the rubber tree contains it as well (Raulf, 2016). This example illustrates the difficulty of differentiating allergens originating from biological agents in the narrow sense — that is microorganisms — from other allergens. The comparatively large size of fungal allergens means that, unlike other allergens, they cannot easily penetrate the lower lung. Fungal spores, however, are particularly small, may easily penetrate the upper and lower respiratory tracts and are especially harmful to the lungs of the immunocompromised (Zukiewicz-Sobczak, 2013; Zukiewicz-Sobczak et al., 2013a). Allergies to spores of fungi occur in the form of inhalation allergies, food allergies, contact allergies (skin reactions) and allergic reaction in response to fungal infection. Spores can also cause infectious diseases.

([21]) Toxins released by living bacterial cells into their surroundings.

([22]) Part of the outer membrane of the cell wall of Gram-negative bacteria. Although the term ‘endotoxin’ is occasionally used to refer to any cell-associated bacterial toxin, in bacteriology it is properly reserved to refer to the lipopolysaccharide complex associated with the outer membrane of Gram-negative pathogens such as *Escherichia coli*, *Salmonella*, *Shigella*, *Pseudomonas*, *Neisseria*, *Haemophilus influenzae*, *Bordetella pertussis* and *Vibrio cholerae*.

Alternaria and *Cladosporium* are the most common fungi outdoors worldwide. Gabrio (2010) reports that in central Europe approximately 200 mould species are estimated to be present indoors and outdoors. Most are associated with specific sources, for example:

- *Cladosporium herbarum*, *Alternaria alternata*, *Botrytis cinerea* — vegetation;
- *Aspergillus fumigatus* — composting, rotting of plant material;
- many *Penicillium* species — perishing foods, decomposing foods, waste, biowaste;
- *Stachybotrys chartarum*, *Acremonium* spp. — very moist, cellulosic construction material;
- *Phialophora* spp., *Engyodontium album* — moist plaster;
- Aspergillus penicillioides, *Aspergillus restrictus*, *Eurotium* spp., Wallemia sebi — cellulosic material with slightly increased moisture;
- *Aspergillus versicolor*, *Chaetomium* spp., *Trichoderma* spp. — moist building fabric;
- *Eurotium* spp. — moist leather (shoes, etc.), animal husbandry;
- *Wallemia sebi*, *Eurotium* spp. — animal caging with litter.

Depending on vegetation, moulds are always present in the ambient air. In central Europe, the concentration of moulds in the ambient air is approximately 100 cultivable mould spores per m^3 in winter and several thousand in summer.

The main indoor fungi are *Penicillium* spp., *Aspergillus* spp. and *Cladosporium* spp. Professional groups particularly exposed to these fungi are workers in the agriculture and food industries, the staff of museums, libraries and archives, and art conservators. The importance of protecting workers during archival tasks was confirmed at the stakeholder workshop (EU-OSHA, 2018a), as the amount of dust in the places where these tasks are performed may lead to significant or high exposure. These groups are expected to come into contact with fungi via ventilation and air-conditioning hoses, stock, settling dust, wooden shelves and barrier constructions (Zukiewicz-Sobczak et al., 2013a). Prester (2011) cites the same three fungi as Zukiewicz-Sobczak et al. (2013a) but adds *Alternaria* spp. These workers may also be exposed to mites and insects, which may exacerbate any allergic reaction, as highlighted in the literature review. According to the German TRBA 240 (ABAS/BAuA, 2010b), the main causes of massive growth and the reproductive processes of moulds, yeast and bacteria in archives are structural deficiencies (e.g. building damp, thermal bridges, leaky roofs, insufficient air exchange rates, rooms that are difficult to clean), excessively high room temperatures and indoor relative humidity, inadequate cleanliness, and excessive water levels and/or excessive near-surface relative humidity in the archival materials. The guidance provides basic information and sets out some measures to apply, for example measures regarding basic facilities (e.g. for hand washing), prohibition of the installation of permanent workplaces in storage facilities, ventilation, requirements for shelves and storage areas, decontamination measures, and the provision of specific PPE in cases of contamination.

Moulds in buildings

In ‘healthy’ buildings, indoor airborne fungi composition is comparable to the fungi composition of outdoor air fungi. However, certain circumstances may result in optimal conditions for fungal growth,

resulting in a composition of fungi in buildings that could lead to ill health. For example, *Stachybotrys atra* and *Stachybotrys alternans*, black fungi, may grow on insulation material and fibreboard inside buildings (Gerardi, 2010), and may pose a risk to, for instance, office workers. In cases of indoor moisture damage, the following 'indicating' mould species are frequently present: *Acremonium* spp., *Aspergillus penicillioides*, *Aspergillus restrictus*, *Aspergillus versicolor*, *Aureobasidium pullulans*, *Chaetomium* spp., *Phialophora* spp., *Stachybotrys chartarum*, *Tritirachium (Engyodontium) album* and *Trichoderma* spp. In the aftermath of natural disasters such as tornados or floods, moulds have optimal conditions for growth. Rescue workers and medical personnel who are required to work under these conditions are at particular risk of an allergic response, and protective measures should be taken. The health effects related to exposure to indoor moulds identified in the literature review were asthma, upper respiratory tract diseases, infections, coughs, headaches and flu-like symptoms, allergic diseases, irritation of the nose, throat, eye and skin, and sick building syndrome ([23]). Workers exposed to indoor moulds include construction workers (including those involved in the removal of hazardous materials), cotton mill workers, those in education and health care, and office workers.

The experts consulted for this report also described prevention measures for occupations that are exposed to moisture damage and, as a result, moulds (Annex 5, Table 18). As regards moisture damage reduction, a Danish expert reported methods for recognising microbial exposure in homes, day-care centres and schools, and the related adverse health effects. There are guidelines as well as training materials for physicians on occupational and basic health care. In addition, data are available on the qualitative and quantitative links between microbial exposure and health.

Five Finnish experts reported measures related to moisture damage/mould problems in buildings. Most of them were transferable to other countries and were targeted at the healthcare sector; however, construction workers and schools were also mentioned. Examples are a training card for construction workers related to moisture control, and updated instructions for occupational health inspectors. In addition, FIOH developed the concept of an 'Indoor Air Group', consisting of representatives of every stakeholder of a building, which regularly meets to solve indoor air problems due to moisture damage and moulds in workplaces at a specific site. A key success factor is that both the employer and the workers, as well as the owner of the building and the OSH organisation, are engaged in the process, which creates a base of support, ensures that realistic solutions are found and ultimately creates a high level of trust within the organisation.

Exposure levels for moulds

In Scandinavia, the Nordic Expert Group has examined the effects on health of moulds capable of producing toxic effects. The level of moulds in the air at which non-sensitised workers start to experience effects was calculated to be about 10^5 spores per m^3 of air. However, no recommendations for an OEL were made (Eduard, 2006, 2009).

A criteria document for fungal spores proposed the lowest observed effect level of 100,000 spores/m^3 for non-pathogenic and non-mycotoxin-producing species, based on inflammatory respiratory effects (Eduard et al., 2012).

3.2.2 Industrial fungal enzymes

Green and Beezhold (2011) reviewed industrial fungal enzymes and found that, in some occupations, workers are at an increased risk of IgE ([24])-mediated disease and occupational asthma. This is especially the case for workers whose occupation requires unbagging, sieving, weighing, dispensing, and mixing enzymes. In some countries, exposure to enzymes in bakeries is one of the leading causes of occupational allergy.

([23]) The term 'sick building syndrome' is used to describe situations in which building occupants experience acute health and comfort effects that appear to be linked to time spent in a building, but no specific illness or cause can be identified (US EPA).

([24]) In the event of an allergy, the immune system overreacts to an allergen by producing antibodies called immunoglobulin E (IgE). These antibodies travel to cells that release chemicals, causing an allergic reaction. This reaction usually causes symptoms in the nose, lungs or throat or on the skin.

Fungal enzymes are used for a variety of purposes across many different industries, for example as purified preparations in the baking, food, detergent, textile and pharmaceutical industries. Many of these are produced by recombinant technology or have been genetically engineered. Exposure usually involves a mixture of many proteins. The most widely used enzymes of occupational importance are derived from the genus *Aspergillus* and include α-amylase, xylanase and cellulase. Other enzymes are also utilised from rhizosphere fungal species belonging to the genera *Rhizopus* and *Humicola*. Lipase is a catalyst that digests water-insoluble lipids used in the manufacture of laundry detergents and in baking. *Aspergillus oryzae* and *Rhizopus oryzae* lipase are used because of low extraction costs, thermal and pH stability, substrate specificity and activity in organic solvents. *Candida antarctica* lipase has been used as a biocatalyst for the biofuel industry. The aspartic proteases produced by *Rhizomucor miehei* and *Cryphonectria parasitica* are used in almost half of the cheese production operations throughout the world. *Aspergillus niger* and *Rhizopus oligosporus* produce phytase, which enhances phosphate bioavailability in the digestive tract and has been used in the animal feed industry; this has led to allergic sensitisation in animal feed factory workers, which is highest at sites where phytase is handled in powdered form.

Fungal enzymes have a number of applications in the healthcare sector. Fungal enzymes derived from *Aspergillus niger* are used in powdered form with other enzyme extracts by pharmacists to prepare digestive powders. Biodiastase and flaviastase have been associated with sensitisation in hospital workers and pharmaceutical workers. Catalase, a fungal enzyme used in hygiene products, pharmaceuticals and textiles, has been identified as an allergen in *Metarhizium anisopliae*. Pectinase is used in brewing and wine production, food processing, and paper industries, and allergy to pectinase has been associated with occupational exposure. Esterase has been identified as an allergen in *Hevea brasiliensis* (natural rubber latex). Beta-glucanase is used to improve the nutritional yield of animal feeds. In the biotechnology and pharmaceutical industries, glutathione-S-transferase has a number of applications. It has also been identified as a major *Alternaria alternata* allergen and is highly conserved across fungi. More than 250 high-molecular-weight allergens that induce occupational asthma have been identified. Green and Beezhold (2011) therefore recommended allergen avoidance strategies, including PPE, engineering controls, protein encapsulation and a reduction in airborne enzyme concentrations.

Allergies in bakery workers

According to the literature survey (EU-OSHA, 2019a), among bakery workers, about 5-10 % suffer from asthma and 15-20 % from rhinitis. Baker's asthma is the most common type of occupational asthma in France, and the second most common in Norway and the United Kingdom. In these occupational settings, occupational asthma is mainly caused by inhalation of cereal flour or powder from wheat, rye, barley, maize or rice (Raulf Heimsoth et al., 2012; Quirce and Diaz-Perales, 2013). Wheat, an allergen of plant origin, is a well-known cause of occupational asthma among bakers, confectioners, pastry factory workers, pasta workers, pizza workers, millers, farmers and cereal handlers (Moscato et al., 2011; Raulf-Heimsoth et al., 2011; Sennekamp, 2011; Raulf-Heimsoth et al., 2012; Sennekamp and Forster, 2012; Raulf, 2016). Several wheat proteins are thought to cause allergies by triggering an immune response. These suspected allergens are the α-amylase/trypsin inhibitor family, lipid transfer proteins, peroxidase, thioredoxin, serine proteinase inhibitors, thaumatin-like proteins and certain prolamins (Quirce and Diaz-Perales, 2013; Raulf, 2016). However, other allergens may also affect bakers, for example enzymes used as flour improvers, legumes, mites, arthropods and moulds (Quirce and Diaz-Perales, 2013). The exact cause cannot easily be elucidated, and a discussion took place between the experts involved in this review on whether to consider these allergic reactions to be caused by chemical factors or biological factors.

The Dutch experts discussed measures for the bakery sector (Annex 5, Table 19). These measures aim to prevent allergies due to exposure to enzymes, often in larger bakeries with sufficient financial resources. In addition, the government is involved in the initial phase, i.e. issues are mapped. Epidemiological studies, perennial surveillance and monitoring studies are performed in this area, which results in evidence that is helpful for raising awareness and identifying areas of concern.

Germany has programmes, provided by the DGUV, to support businesses in preventing respiratory infections, allergies and irritations caused by pathogens and allergens from trade products among bakery workers. These measures consist of field safety assessments and surveillance (support for workplace risks assessments), a helpdesk (telephone) for questions from enterprises, seminars, on-the-spot work safety presentations and conferences, site-workplace field measurements, the implementation of prevention measures, a sample analysis and a systematic evaluation (efficiency control of the implemented prevention measures). A reliable and confidential long-term working relationship with businesses and the possibility of providing direct feedback are other facilitating factors. Some of the hindering factors mentioned were insecurity about the root cause of diseases, that is when symptoms cannot be related to the disease, which complicates the evaluation; and the lack of compliance with the measures. It was also noted that habits are difficult to change in bakeries, that is risks are seen as inherent to the job and there is a certain reluctance to change work procedures, for example to avoid flour dust.

Exposure limits for flour dust and industrial enzymes

In the Netherlands, reference values of 0.012 mg inhalable flour dust/m³ (8-hour time-weighted average, TWA) for occupational exposure to wheat and other cereal flour dusts, 0.9 ng enzyme/m³ (8-hour TWA) for occupational exposure to fungal alpha-amylase, and 0.1 µg inhalable soy antigen/m³ (8-hour TWA) for occupational exposure to dust from processed de-hulled soybean flour are derived, related to a sensitisation risk of 1 % compared with the background risk of the general population (Health Council of the Netherlands, 2004, 2014, 2016).

In the case of flour dust, Sweden has recommended a level limit value of 3 mg/m³ (8-hour TWA), the United Kingdom has recommended a maximum exposure level of 10 mg/m³ (8-hour TWA) and of 30 mg/m³ (15-minute TWA) and the American Conference of Governmental Industrial Hygienists (ACGIH) ([25]) in the United States has recommended a threshold limit value (TLV) for inhalable flour dust of 0.5 mg/m³ (8-hour TWA). The ACGIH has also established a TLV for subtilisin, an enzyme of bacterial origin that is used as, for example, a detergent and is produced with the aid of genetically modified organisms (GMOs).

3.2.3 Bacteria and allergies

Bacteria exposure inducing hypersensitivity pneumonitis is a risk in agriculture, food processing, the work of technicians (e.g. humidifier and ventilation system workers, machine operators), floristry and the detergent industry (Quirce et al., 2016). Although both bacteria and fungi have been identified as causal agents of hypersensitivity pneumonitis, bacteria, particularly thermophilic actinomycetes such as *Saccharopolyspora rectivirgula* (Blais-Lecours et al., 2014; Cano-Jimenez et al., 2016), *Thermoactinomyces vulgaris*, *Thermoactinomyces viridis* and *Thermoactinomyces sacchari* (Cano-Jimenez et al., 2016), are reported as primary agents.

Pantoea agglomerans should be regarded as one of the major causative agents of work-related diseases in the cotton industry, the grain industry and agriculture, which are caused by the adverse effects of protein allergens and endotoxins produced by this bacterium (Dutkiewicz et al., 2015, 2016).

([25]) The ACGIH is a professional association of industrial hygienists and practitioners of related professions, with headquarters in Cincinnati, Ohio, United States. One of its goals is to advance worker protection by providing timely, objective, scientific information to occupational and environmental health professionals. ACGIH establishes the threshold limit values (TLV) for chemical substances and physical agents, and biological exposure indices (BEIs).

Woodworking and metalworking industry

Other well-researched areas include allergens in the woodworking and metalworking industry that have similar bacterial and fungal microorganisms to causative agents. Contamination of metalworking fluids by biological agents causes a new pattern of health problems and is examined in many articles. Occupational exposure to microorganisms in metalworking fluids, for instance in the metalworking industry, occurs mainly through direct contact with skin and inhalation, the latter indicating a possible relationship with occupational asthma and hypersensitivity pneumonitis (Barber et al., 2012; Burton et al., 2012) and/or possibly sarcoidosis (Newman and Newman, 2012). The agents are most often Gram-negative bacteria, opportunistic mycobacteria and fungi, growing in an antibiotic-resistant biofilm. Fast-growing mycobacteria such as *Mycobacterium immunogenum* and *Mycobacterium chelonae* are suspected to be the cause of hypersensitivity pneumonitis in the metalworking industry (Quirce et al., 2016). They are also implicated in hypersensitivity pneumonitis in machine operators (Zacharisen and Fink, 2011; Quirce et al., 2016). Hypersensitivity pneumonitis in metalworkers is also associated with exposure to *Pseudomonas* sp., *Acinetobacter* and *Ochrobactrum* (Darby and Fishwick, 2011).

Cutting fluids represent a health hazard to workers for several reasons. Chemicals may be irritating or toxic to the skin and respiratory tract through aerosol generation during turning. As it may not be possible to use gloves when handling machinery with turning parts because of the risk of entanglement and injury, the skin of the hands may be particularly exposed. Water-miscible cutting coolants also provide an environment that encourages the development of microorganisms, particularly bacteria and fungi, which can release sensitising cellular breakdown products and metabolites such as endotoxins and mycotoxins. In addition, as the technical functions of the fluids can be compromised by microbial growth, biocides are generally applied. The generation of inhalable aerosols mainly occurs at the tool-workpiece interface. However, machinery can be fitted with various types of shielding to reduce the aerosol exposure of workers.

Rosenman (2015) reported that, since 2005, the number of asthma cases related to metalworking fluids had decreased, possibly owing to the stricter air standard introduced in 1998 (from 5 mg/m^3 to 0.5 mg/m^3 of metalworking fluids in air) and the concurrent introduction of new equipment to meet this standard.

As highlighted in the literature review, the German DGUV has also published reports on the bioburden of water-miscible cutting coolants, which state that microorganisms thriving in these types of cutting coolants are widespread and include frequently occurring environmental bacteria belonging to Risk Groups 1 and 2 (DGUV, 2011, 2016a). However, no limits or guidance values are available to help in assessing the microbial colonisation of water-based cutting fluids, and, with regard to the policy measure to prevent respiratory and skin allergies and irritation in metalworking, the lack of a limit value concept was also mentioned as an obstacle by the experts.

3.2.4 Organic dust and effects of toxins

Organic dust and bacterial and fungal endotoxins produce a wide range of effects, including infections, toxic effects, carcinogenic effects and allergenic effects; these are presented in Tables 16-19 of the literature review (EU-OSHA, 2019a).

Organic dust, sometimes referred to as bioaerosols, is potentially harmful because of the huge variety of components it may include, such as plant proteins, animal proteins, bacteria and fungi, and their metabolites. Grain dust, for example, is a complex mixture of organic and inorganic materials, mainly cellulose-based seed coating and carbohydrate. It may also contain bacterial and fungal contamination, and the associated endotoxin and mycotoxin, mites, insects, and small amounts of crystalline silica (Spankie and Cherrie, 2012).

Organic dust is a common cause of allergic respiratory diseases, as already highlighted in the sections on specific occupations — especially animal-related occupations — above. For example, health statistics show that most of the occupational diseases of allergic origin reported in Polish farmers are caused by pathogens present in organic dust. In Poland, as in other countries, lung diseases are more common in farmers than in the rest of the population (Zukiewicz-Sobczak et al., 2013b). Organic dust can lead to allergic diseases such as hypersensitivity pneumonitis, bronchial asthma, allergic rhinitis or allergic conjunctivitis and dermatitis. Components of dust can also cause the development of diseases with immunotoxic effects such as sick building syndrome, or cause ODTS, common in swine workers and people exposed to grain dust (Zukiewiciz-Sobczak et al., 2013a). Occupational rhinitis and asthma often co-exist. According to Montano (2014), bioaerosol exposure of veterinarians, farmers and agricultural labourers is related to hypersensitivity reactions, whereas farmers and workers in veterinary settings, workers in grain threshing and sieving, flax threshing, herb processing, composting and wood processing and those handling silage have an increased risk of chronic respiratory disorders associated with intense exposure to allergenic microorganisms (e.g. bacteria and fungi) and related pathogenic and toxic substances (Alonso et al., 2013; Wéry, 2014). The main pathway leading to exposure is by inhalation of particles, which then reach the respiratory system. Particle deposition in lungs is closely related to the size of the particles. Many of the bioaerosol particles emitted by compost, for example, are very fine and can reach down the pulmonary alveoli. The issues related to respiratory disorders have been addressed above in relation to compost workers. Dust-avoiding measures are therefore of great importance in this sector. The size of spores of moulds colonising compost (*Aspergillus*, *Penicillium*) is below 3 µm, and the size of thermophilic actinomycetes is around 1 µm (Wéry, 2014). Rohr et al. (2015) reviewed dust concentrations within biomass plants and found that they can be extremely variable, with peak levels in some areas exceeding OELs for wood dust and general inhalable dust. Fungal spore types, identified as common environmental species, were higher than in outdoor air. They therefore concluded that measures needed to be taken and the exposures needed to be further assessed. Biomass also has a tendency to decompose, creating changing exposure scenarios and requiring different handling, transport and storage considerations to minimise both microbial growth (e.g. spore formation, endotoxin release) and off-gassing of volatile organics or other gases (e.g. carbon monoxide).

Textile dust-related obstructive lung disease has characteristics of both asthma and COPD. The adverse respiratory effects of exposure to cotton, flax and hemp dust in the textile industry was first described several centuries ago as a syndrome later called byssinosis. The mechanisms due to textile dust-related endotoxin exposure linked to the development of persistent airway inflammation and associated airflow obstruction were described in a review by Lai et al. (2014). A German study on endotoxin exposure in natural fibre textile processing and manufacturing (Kraus and Koppisch, 2007) shows that, depending on their origins, as well as on the degree of contamination and on the processing methods, moulds, bacteria, endotoxins and other substances are released during the processing of natural fibres. A large variation in endotoxin values was observed, which did not correlate with the observed dust concentrations. Microbe-contaminated raw cotton fibres caused the highest bacteria and endotoxin

emissions in spinning mills, with levels decreasing from around 2,000 endotoxin units ([26]) (EU)/m³ to around 10 EU/m³ during the course of the spinning process. In cotton-knitting mills the measured values were around 120 EU/m³, and in weaving mills around 70 EU/m³; even lower values were observed for mixtures with synthetic or other fibres. Primary technical measures reduced inhalation exposure, and PPE was considered necessary when carrying out maintenance of ventilation equipment. The authors state that preventive measures, along with occupational medical prevention, are more practical means of avoiding work-related health impairment than health-based limit values.

Exposure to mycotoxins and endotoxins of bacterial origin was also addressed in two position papers by the German advisory body ABAS (2005, 2007). Mycotoxins are metabolites of fungi, some of which are carcinogenic. In addition, individual mycotoxins also have mutagenic, toxic, teratogenic and immunotoxic effects. In workplaces, exposure to mycotoxins is through inhalation and the skin. This is likely to be the case with, for example, activities involving organic materials such as animal feed, food and waste. Various studies suggest that, depending on the level of exposure, both acute and chronic effects are possible. So far, well over 300 various mycotoxins are known, which are assigned to about 25 structure types.

Workers in sewage plants, poultry sheds, sawmills and material-recycling facilities are particularly exposed to high levels of respirable endotoxins, which lead to chronic bronchitis and diminished lung function (Wallace et al., 2016). Increasingly, feed additives for livestock, such as amino acids and vitamins, are being produced by Gram-negative bacteria, particularly *E. coli*. Workers can therefore be exposed to possibly harmful amounts of endotoxin from these products (Wallace et al., 2016).

Ochratoxin A is a nephrotoxic mycotoxin that has received particular attention because of its toxic effects, its widespread occurrence in the contaminated food and feed chain, its suspected causal effect on nephropathies and, more recently, the possibility of exposure via inhalation in occupational settings. It has also been proven to induce diverse toxic effects, including teratogenicity, carcinogenicity, immunotoxicity and potential endocrine disruption (Duarte et al., 2011; Woo and El-Nezami, 2016). An overview of exposed occupations is provided in the literature review.

Exposure levels for organic dusts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A health-based recommended OEL for inhalable grain dust of 1.5 mg/m³ (8-hour TWA) was considered sufficient protection for workers with acute, short-term and chronic exposure (compared with the TLV derived by the ACGIH of 4 mg/m³ for total grain dust — wheat, oats, barley — and a workplace exposure limit for grain dust of 10 mg/m³ established by HSE in the United Kingdom) (Health Council of the Netherlands, 2011).

Exposure levels for endotoxins

Exposure levels are set for some organic dusts such as grain dust, but the endotoxin levels are not correlated with the dust levels; therefore, separate measures would be needed, as well as measures for, for example, mite allergens (Spankie and Cherrie, 2012).

A German study on endotoxin exposure in the workplace (Kolk and Koppisch, 2007) was based on 1,681 air samples covering endotoxins from the German MEGA database. The measurements were mostly from textile plants (394 measurements), agriculture, wholesale trade and warehousing, and waste incineration. The DGUV's Biological Agents Unit has more recently analysed the MEGA data for concentrations of moulds and endotoxins in workplaces. An extract from this analysis has been published in TRBA 400 on risk assessment (ABAS/BAuA, 2017), which has been

([26]) Because endotoxin molecular weight may vary a great deal (10,000-1,000,000 Da), endotoxin levels are measured in endotoxin units (EU). One EU is approximately equivalent to 100 pg of *E. coli lipopolysaccharide* — the amount present in around 105 bacteria. Humans can develop symptoms when exposed to as little as 5 EU/kg of body weight. These symptoms include but are not limited to fever, low blood pressure, increased heart rate and low urine output; even small doses of endotoxin in the bloodstream are often fatal.

updated to take this information into account. According to TRBA 400, for the assessment of exposure to airborne biological agents, no health-based limit values exist. To be able to assess the level of airborne exposure, workplace concentrations are compared with the average concentrations in the ambient air. For mould fungi, the annual average background concentration in the ambient air is around 1,500 colony forming units (CFU)/m³. In workplaces, mould fungi concentrations of > 10^9 CFU/m³ may occur depending on the activity. For endotoxins, the annual average ambient air concentration is estimated at 7 EU/m³ according to TRBA 400. TRBA 400 also assigns exposure levels for airborne endotoxins as follows:

- Exposure level 'increased': 100 (10^2) to 1,000 (10^3) EU/m³.
- Exposure level 'high': 1,000 (10^3) to 10,000 (10^4) EU/m³.
- Exposure level 'very high': over 10,000 (10^4) EU/m³.

Workplace measurements of endotoxins are also reported from Finland, France and the Netherlands. Measurements are available from studies by the German statutory insurance institutions and the research institution BAuA, as well as the OSH research institutions in Finland and France, and there are standardised methods for measuring the concentration of endotoxins in air (EN 14031).

In the Netherlands, a health-based recommended OEL was derived for endotoxin exposure (90 EU/m³ 8-hour TWA) (Health Council of the Netherlands, 2010).

Measures for SMEs

Although hardly any information was retrieved regarding SMEs in the literature survey, the experts and practitioners involved in this study agreed that the management of biological agents may be challenging for SMEs, given their lack of knowledge and awareness. Consequently, training and awareness-raising were recognised as particularly important in SMEs.

During the stakeholder workshop, participants confirmed that SMEs lack financial means for addressing health risks and exposure to biological agents. The low number of workers in SMEs restricts the possibility of sending workers to informative meetings or training sessions. One way in which to reach SMEs could be the implementation of policy measures at the municipal level, which may create a more direct approach between the local government and SME owners, resulting in more communication and awareness. In the United Kingdom, an 'SME2box' — a successful, freely accessible tool that presents an overview of health and safety issues, and risk assessment guidance — is available. In Denmark, financing is available for developing courses for SMEs. In Belgium, SMEs are reached by consultants visiting specific sectors that have a large proportion of SMEs, such as hairdressers. One participant recommended providing very short, sector-specific information to SMEs. Italy has provided subsidies since 2010 for enterprises that want to improve their working conditions, including controlling risks due to biological agents. In Ireland, a tool called 'BeSmart' (Business Electronic Safety Management and Risk Assessment Tool) aims to help business owners/managers prepare a risk assessment and safety statements for the workplace. The tool highlights the main hazards in a sector and covers biological agents. In the Netherlands, Stigas ([27]) provides a tool for entrepreneurs and workers in the agricultural sector.

3.3 Vulnerable groups

One of the objectives of the project was to identify vulnerable workers for whom specific measures should be taken. The review focused on identifying those groups of workers that are considered vulnerable because of a lack of experience or training or because of physiological or social vulnerability. The critical doses, and the circumstances of exposure, may be different for these groups. For most occupations, however, vulnerable groups, with the exception of young and new workers, were not specifically mentioned in the literature in relation to risks due to biological agents, indicating an

([27]) Stigas is an independent knowledge institute that works for all agricultural and green sectors. Stigas stimulates employers, employees and the self-employed in the agricultural and green sectors to work healthily, safely and sustainably. Their services include (1) legally required activities such as risk inventory, risk evaluation and preventive medical research; (2) information and training for machine safety, hygiene and healthy movements during work; and (3) programmes for areas such as sustainable employability.

significant data gap that should be addressed. They are not considered in the research, except in relation to some allergens. Furthermore, during the evaluation of the selected monitoring systems (see also Section 3.5), it was observed that a relatively limited number of data is available on the prevalence of certain diseases, for which the link to certain workplace exposures is not always clear. Given that, in general, no distinction is made in the (publicly available) report on the data collected by the various monitoring systems between, for instance, age groups and/or male and female workers or the type of work contract, it is hard or even impossible to link this output to specific vulnerable groups.

It should be borne in mind, however, that EU OSH legislation has highlighted young workers and pregnant and breastfeeding women and their children as groups that warrant particular attention, and this applies in particular in relation to biological agents. This was confirmed by the literature review and the discussions with experts, who identified additional groups that need to be considered and the fact that specific and more protective prevention measures may need to be established for them when they are exposed or potentially exposed to biological agents.

As mentioned above, two groups that emerged as vulnerable across all sectors were trainees and workers in their first job. Other groups that were identified through the qualitative research and the discussions at the stakeholder seminar include pregnant women; people with pre-existing diseases and conditions, such as lung diseases, allergies and asthma; people who suffer from diabetes (because of the increased risk of infection); people with (other) chronic diseases; people treated with immunosuppressants; cleaning and maintenance workers; and temporary and undocumented workers or foreign workers. Another socially vulnerable group identified in the review is sex workers; prevention programmes targeting these workers need to take into account wider social issues, such as the prevention of human trafficking and violence, and the social support schemes available to these workers. During the focus group sessions, the experts also discussed the facts that older workers are more susceptible to health problems, that this group is generally increasing in size because of the ageing of the working population and that this may be even more relevant in some sectors, such as farming.

3.3.1 Young workers

A recurring theme in the output from the scientific literature review was the vulnerability of trainees and workers in their first job. Their vulnerability is linked to a lack of experience and training, and they may also have a physiological vulnerability. This may also be reflected by the fact that younger workers (less than 21 years and 21-30 years) are slightly over-represented in prevalence reports on registered occupational diseases relevant to biological agents. This points to a need to improve training programmes for new workers in work sectors and occupational groups that are identified as being at high risk of biological agent- or allergen-related diseases. With regard to trainees and young workers, the experts also indicated that OSH is often not a major theme during the training period or in vocational education, and therefore this group often lacks knowledge of, for instance, the basic principles of hygiene.

Nurses in training or young healthcare workers are reported to be a vulnerable group for hepatitis B infections (Zandi et al., 2011) and measles in countries with low vaccine coverage (Fiebelkorn et al., 2014). Medical trainees are also at considerable risk of contracting HIV and other locally endemic diseases such as malaria, dengue fever, traveller's diarrhoea and sexually transmissible infections, as well as nosocomial transmission of blood- or body fluid-borne pathogens such as hepatitis B and hepatitis C, when they participate in the healthcare systems of resource-poor countries (Kortepeter et al., 2010, Mohan et al., 2010; Panosian, 2010; Rossouw et al., 2014).). In line with the results of the scientific literature search, the Dutch experts also mentioned (medical) students as a vulnerable group.

Also within this group of vulnerable workers are young cooks, who reportedly experience seafood allergy after a median of 1.7 years after beginning their employment, although in these cases natural susceptibility may also play a role in addition to their being workplace novices. According to one study, the majority experienced immediate sensitisation, with a considerable proportion (16.7 %) of the sensitised individuals experiencing anaphylactic shock (Dickel et al., 2014).

The EU directive on young workers ([28]) lays down a specific focus on risk assessments on young workers and potential risks to them. An assessment must be made before young people begin work and when there is any major change in working conditions, and it must pay particular attention to the nature, degree and duration of exposure to physical, biological and chemical agents, the work processes and the level of training and instruction given to young workers. According to the directive, where this assessment shows that there is a risk to the safety, the physical or mental health or the development of young people, appropriate free assessment and monitoring of their health must be provided at regular intervals. The employer must inform young people of possible risks and all measures adopted concerning their safety and health, and involve protective and preventive services in the planning, implementation and monitoring of the safety and health conditions applicable to young people. Work involving harmful exposure to biological agents, namely those in Risk Groups 3 and 4, is prohibited. Measures should take into account the vulnerability of young workers, whose bodies may still be developing, and for exposure to biological agents this may also include their immune status, effects on development and fertility, and especially the development of allergies.

3.3.2 Pregnant workers

Pregnant workers are also a vulnerable group, especially in health care. Although HIV has been assessed to be of the greatest concern to pregnant orthopaedic surgeons because of the potentially fatal health consequences for the foetus if the mother goes untreated (Keene et al., 2011), in general other studies (Downes et al., 2014) have identified no additional risk with regard to HIV or hepatitis for pregnant or lactating workers.

Pregnant healthcare workers with occupational exposure to communicable diseases should, however, be evaluated immediately for appropriate post-exposure prophylaxis and monitored for the development of active infection (Lynch and Spivak, 2015). As pregnancy does not seem to be an independent risk factor for healthcare workers, primary prevention with vaccination and the use of appropriate infection control precautions is imperative to prevent occupationally acquired infectious diseases, as for all healthcare workers (Chin et al., 2014). The focus group sessions also revealed that pregnant workers may be more vulnerable to exposure to organic dust, which is particularly relevant in agriculture and animal-related occupations, and therefore may also be an issue when treating or handling animals. Furthermore, in all the professions described as being at risk in this review, the specific risks to pregnant workers or foetuses and to breastfeeding should be taken into account. Pregnant healthcare workers are also particularly at risk of hepatitis E virus infection.

There are a number of biological agents that may have teratogenic effects and may harm foetuses, and pregnant and breastfeeding workers should be included in the workplace risk assessment, ideally before any female worker becomes pregnant, and the measures set out for their protection, as laid out in the

([28]) Directive 94/33/EC of 22 June 1994 on the protection of young people at work.

related EU directive ([29]). Under the directive, a set of guidelines detail the assessment of the chemical, physical and biological agents and industrial processes considered dangerous for the health and safety of pregnant women or women who have just given birth and are breastfeeding. Employers or the health and safety service will use these guidelines as a basis for a risk evaluation of all activities that pregnant or breastfeeding workers may undergo and must decide what measures should be taken to avoid these risks. For all activities likely to involve a specific risk of exposure, the employer must assess the nature, degree and duration of exposure in the undertaking and/or establishment concerned, either directly or by way of the protective and preventive services referred to, in order to assess any risks to safety and health and any possible effect on the pregnancy or the breastfeeding of the workers, and decide what measures should be taken. This includes biological agents in Risk Groups 2, 3 and 4, insofar as it is known that such agents or the therapeutic measures necessitated by them endanger the health of pregnant women and their unborn children, and specific biological agents in Annex II to the directive — toxoplasma and rubella virus — unless pregnant workers prove to be adequately protected against such agents by immunisation. Workers should be notified of the results and measures to be taken, which can be an adjustment of working conditions, a transfer to another job or the granting of leave. Pregnant and breastfeeding workers may under no circumstances be obliged to perform duties for which the assessment has revealed a risk of exposure to agents, as this would jeopardise their safety and health. Those agents and working conditions are defined in Annex II to the directive.

3.3.3 Immunosuppressed workers

Some risks may arise from an increase in immunosuppressive treatment (e.g. chemotherapy) methods among the general population. Unfortunately, these people are at an increased risk of infectious diseases, for example in relation to fungal and viral infections.

Histoplasma, *Coccidioides*, *Cryptococcus* and *Blastomyces* are fungi known to infect immunocompetent individuals, whereas immunocompromised patients are susceptible to infection with *Candida* and *Aspergillus* (Gerardi, 2010; Gangneux et al., 2012). Immunocompromised people (e.g. transplant recipients and HIV-infected patients) as well as people with a pre-existing liver disease are also vulnerable to hepatitis E infections.,. Another vulnerable group for contracting, for example, zoonoses from contact with animals are people with peritoneal dialysis (Broughton et al., 2010).

The higher risk of infectious diseases due to the increased use of immunosuppressive treatment methods was also addressed by the experts in the focus groups. The Danish experts claimed that vulnerable groups in health care are, in general, people with chronic diseases; they are more susceptible because of their reduced immune defence. The Dutch experts highlighted vulnerable groups in health care in general: patients, travellers or travelling health workers. Travellers may be unaware that they have been in areas with serious endemic diseases (for instance Ebola) and may return home with vague health complaints, putting healthcare workers at risk.

Expert opinions differ on whether or not those who are immunosuppressed ([30]) are a vulnerable group (EU-OSHA, 2018a). However, there is agreement on those who are immunocompromised ([31]): information should be more specific, and guidance should include information and rules for immunocompromised individuals.

Another issue was raised in the stakeholder workshop to discuss the preliminary results of this review: the German advisory body ABAS is investigating the relationship between stress factors and exposure to biological agents. Acute stress may lead to mistakes, consequently increasing the risk of accidents, for example needlestick injuries in health care. Long-term stress may also increase individual

([29]) Directive 92/85/EEC of 19 October 1992 on the introduction of measures to encourage improvements in the safety and health at work of pregnant workers and workers who have recently given birth or are breastfeeding (tenth individual Directive within the meaning of Article 16 (1) of Directive 89/391/EEC).

([30]) Immunosuppression is a reduction in the activation or efficacy of the immune system. Deliberately induced immunosuppression is performed to prevent the body from rejecting an organ transplant. In addition, it is used for treating graft-versus-host disease after a bone marrow transplant, or for the treatment of auto-immune diseases such as systemic lupus erythematosus, rheumatoid arthritis, Sjögren's syndrome and Crohn's disease.

([31]) Patients who are immunocompromised have a reduced ability to fight infections and other diseases. This may be caused by certain diseases or conditions, such as AIDS, cancer, diabetes, malnutrition and certain genetic disorders.

susceptibility through effects on the immune system (immunosuppression and immunomodulation), which may affect an individual's defences against infections, sensitisation or toxic effects (Förster, in EU-OSHA, 2018a).

The focus group sessions revealed that the workers who may be more vulnerable to exposure to organic dust are pregnant women; people with pre-existing diseases and conditions, such as lung diseases, allergies and asthma; people who suffer from diabetes (because of the increased risk of infection); and people with (other) chronic diseases. As organic dust was recognised as a priority issue in both animal-related occupations and waste treatment, the vulnerable groups are similar in both sectors.

3.3.4 Cleaners and maintenance workers

The Dutch experts also considered cleaners an important group, as they are prone to very diverse exposures and often perform risky tasks. Cleaners may work for different employers and at several premises. In addition, internal and external cleaning services may differ regarding, for instance, who is responsible for providing information on risks and safety measures, the provision of PPE and the vaccination of personnel. Cleaners may fall short of being covered by preventive services or prevention initiatives specific to exposure to biological agents, such as vaccination programmes. In addition, doubts were raised over the quality of the tools that are used for cleaning and how to ensure that prevention measures are implemented by these workers. This is confirmed by the results of the literature review.

Furthermore, a study of laundry workers who handle hospital textiles showed that they may be at risk of infection from contamination of quite serious agents, for example *Sarcoptes scabei*, *Microsporum canis*, *Salmonella typhimurium/hadar* and the hepatitis A virus (Fijan et al., 2012). Cleaners may also be at risk of needlestick injuries, and preventive measures should therefore cover them, along with the risk of contamination and injuries through waste.

Maintenance workers/repair workers were considered to be at higher risk owing to a lack of awareness and clear rules (one example described was that of maintenance workers of cooling systems and water-based systems, who may, for example, be at risk of *Legionella* infection). The experts considered cleaning and maintenance high-risk jobs in some of the sectors described in this review, such as the waste treatment sector. In addition, they may not be as well covered by rules and regulations. In Denmark, for example, the maintenance sector is not covered by the national legislation implementing the directive and is not regulated by the same authorities as other occupations in which exposure to biological agents is considered a risk. Among maintenance occupations, awareness is low, which causes problems.

3.3.5 Migrant and temporary workers

The experts also indicated that temporary workers and undocumented workers are considered a more important vulnerable group in both animal-related occupations, especially farming, and the waste

treatment sector, because they are often unaware of and uninformed about the risks that they are exposed to, frequently do not receive the appropriate instructions and do not have access to preventive measures, for example appropriate vaccinations.

Foreign and migrant workers were considered a relevant group because of language problems. This group of workers may be fluent in only their native language; consequently, they do not always understand guidance and/or safety instructions if these are provided in the language of the country in which they are working (or in English). It was mentioned that this problem is especially prevalent among workers from eastern Europe who migrate to western Europe.

Temporary workers were considered a relevant group because of their lack of training and the challenges posed by constantly changing employers and work environments. A lack of training may result in a higher rate of accidents and increased (unawareness of) exposure risk. For example, in waste handling, temporary personnel are often hired through employment agencies, and this was highlighted as an issue by the experts consulted for this report. In addition, they may not have been considered in the implementation of prevention measures; for example, they may not have been included in companies' vaccination programmes.

3.4 Emerging risks

One of the objectives of this review was to collect information on emerging risks related to exposure to biological agents at work, the related health problems and how these could be prevented. The concept of emerging risks covers newly created or newly identified risks, growing risks and risks that are becoming more widely known or established. The definition of emerging risk was first included in an EU-OSHA forecast of emerging biological risks (EU-OSHA, 2007).

An 'emerging OSH risk' is often defined as any occupational risk that is both new and increasing.

'New' means that:

- the risk was previously unknown, and is caused by new processes, new technologies, new types of workplaces, or social or organisational change;
- a long-standing issue is now considered a risk because of changes in social or public perceptions;
- new scientific knowledge identifies a long-standing issue as a risk.

A risk is classed as 'increasing' if the number of hazards leading to the risk is growing, if the likelihood of exposure to the hazard leading to the risk is growing (exposure level and/or the number of people exposed), or if the effect of the hazard on the worker's health is getting worse (seriousness of health effects and/or the number of people affected).

Some of the risks identified in this study as being related to biological agents in Europe are newly created risks that are, for example, becoming widely known or established, including new bacteria developed through bioengineering and increased exposure to bacteria and fungi due to the increased collection and separation of organic waste.

3.4.1 Emerging risks and their causative factors based on the scientific literature review

Risks emerging in Europe that are linked to exposure to biological agents at work, as detected by the literature review, include Rift Valley fever, yellow fever, malaria, dengue fever, chikungunya and Crimean-Congo haemorrhagic fever. Owing to the huge migration flow in recent years, the risk of transfer of biological agents from the Middle East and Africa to Europe, as well as climate change, is considered a significant factor from this perspective.

The expert forecast on emerging biological risks indicated that livestock may act as a reservoir of biological agents, potentially resulting in global epidemics or zoonoses, covering diseases such as SARS, avian flu, Ebola and Marburg virus infections, cholera, dengue fever, measles, meningitis, yellow fever, Q fever, legionellosis, tuberculosis and tularaemia, all of which may be particularly relevant to workers in animal-related occupations (EU-OSHA, 2007). This was confirmed by the research in this review, which identified a wide range of possible zoonoses in these workers, and the experts addressed in the interviews and focus groups confirmed this. In addition, there may be a wider spread of these diseases because of climate change, changes in the way sectors are organised, for example for breeding and the transporting of animals, changes in travelling patterns, economic changes, and the movement of goods and migration caused by the globalisation of the economy. The recent coronavirus epidemic is one example of such an impact. An overview of the many diseases and biological agents causing them is provided in the literature review (EU-OSHA, 2019a).

The hepatitis E virus appears to be an emerging problem in several industrialised countries, where it is mostly associated either with travelling to a hepatitis E virus-endemic area, for example among airline personnel (EU-OSHA, 2007), or with contact with pigs (which are a major reservoir of hepatitis E virus).

Climate change is considered a significant factor with respect to newly created risks in that it influences the geographical range of the vectors (ticks, mosquitoes) of biological agents, thereby facilitating the spread of diseases that are new to a region. Among the diseases identified in this review are Rift Valley fever, yellow fever, malaria, dengue fever and chikungunya (Applebaum et al., 2016). Evidence has also been confirmed of Crimean-Congo haemorrhagic fever, which is endemic to the Balkans, Spain and Portugal — a circumstance that suggests the possibility of further spread.

Changing patterns in human behaviour, notably travel behaviour, are also considered to be a major factor in emerging risks. Indeed, travelling was indicated by questionnaire respondents as a reason for paying more attention to certain biological agents and the illnesses they cause. In general, transport workers (airline personnel), customs workers and border guards, global trade workers, workers in war zones, epidemic control (field) epidemiologists, journalists and media professionals are likely to be at risk of contracting diseases that leisure and business travellers are at risk of contracting. This includes the risk of contracting avian flu, Q fever, dengue fever, Ebola/Marburg virus infection, tularaemia, legionellosis, measles, tuberculosis, yellow fever, SARS, cholera and meningitis (EU-OSHA, 2007,

2018a). Hepatitis E associated with travelling to endemic areas is of particular concern for vulnerable persons.

Despite the greatly increased movement among populations from very diverse regions (including Asia, the Middle East and Africa) to the European region, research on the transfer of biological agent-related diseases from populations outside the region was limited to only one publication, which described the import of malaria cases in Europe as a result of European-settled immigrants returning from visiting friends and family in their country of origin (Monge-Maillo and López-Vélez, 2012), without, however, an occupational context. Nevertheless, owing to the large migration flow that has been apparent in large parts of Europe in recent years, the transfer of biological agents from the Middle East and Africa may need to be given extra focus, especially among the groups of workers who are in first contact with migrants (e.g. healthcare workers, social workers, rescue workers and customs workers). The fact that vaccination programmes for diseases such as pertussis and malaria, which are most commonly associated with developing countries, now exist in EU Member States suggests that some countries (e.g. the Netherlands and the United Kingdom) recognise the importance of (work) travel in relation to the distribution of diseases within and from outside the EU region.

Other emerging diseases were seen in central and eastern Europe among veterinarians, with cases of human dirofilariasis noted as an emerging zoonosis (Dutkiewicz et al., 2011) and infections due to the fungus *Sporothrix schenckii* (inducing sporotrichosis) reported as a new risk category (Barros et al., 2011). Furthermore, re-emerging diseases (for instance Q fever, tuberculosis and influenza) should be considered among emerging risks.

3.4.2 Identification of new and/or emerging risks

Detection

First case reports may sometimes be indicative of a new/emerging risk. The first case reports reported in the literature search were predominantly concerned with the first cases of allergen-related occupational asthma, caused by a heterogeneous range of allergens. They were mainly observed in (roughly) three industries or types of occupations: the food industry; occupations in which workers purposely or inadvertently come into contact with animals; and occupations in which workers deal with plant products. In the food industry, the first cases of occupational asthma were seen in the coffee industry, in semi-industrial pork butcheries, in connection with mushrooms at a greengrocers, among seafood-processing workers exposed to aerosolised octopus allergens and turbot, among olive oil and rice mill workers, and among machine operators at a malt company (Quirce and Bernstein, 2011; Quirce and Sastre, 2011). In occupations that involved contact with animals, the first cases of occupational asthma were observed among animal rescue workers who dealt with roe deer, biologists who handled gerbils, and greenhouse workers who were exposed to predatory mites, and in an engineer who was exposed to caddis flies when working for an electric power company (Quirce and Bernstein, 2011; Quirce and Sastre, 2011). Quirce and Sastre (2011) reported the first case of allergen-related occupational asthma caused by *Chrysonilia sitophila*, which affects workers in the coffee industry, and the first case of allergen-related occupational asthma caused by *Penicillium nalgiovensis*, which involved a worker at a semi-industrial pork butcher. Moreover, new causes of occupational asthma have been reported, namely sausage mould among semi-industrial pork butchers, and mushrooms in greengrocers (Quirce and Bernstein, 2011). With respect to plant-related allergens, the first cases were observed among plant breeders in connection with exposure to cauliflower and broccoli pollen; among greenhouse workers in connection with tomatoes; among herbal product traders; in a worker packing camomile tea; and among laboratory plant workers (*Arabidopsis thaliana*). Other notable first cases of occupational asthma concerned famers (cellar spider), exposure to wood among carpenters (cedrorana, chengal wood) and parquet floor layers (cabreuva wood), a chemist (linseed oilcake), a brush maker (tampico fibre), and exposure of pharmaceutical workers to papain.

Some of the monitoring systems analysed in the literature review, such as the French RNV3P system, allowed the identification of such first case reports, the validation of them within the system and against the literature, and the issuing of alerts to a prevention network that might in turn encounter such cases in practice and feed them back into the system, further validating the first case reports An example of

such a report was an allergy caused by *Chrysonilia sitophila* in a coffee machine maintenance worker. Within the system that is in place for monitoring work-related diseases in France (the rn3vp system, see Section 3.4), information about warning signs is exchanged to prevent the spread of emerging zoonotic diseases of which registration is not mandatory (e.g. psittacosis, Lyme disease, Q fever). A network of professionals from (occupational) health services who participate in multidisciplinary teams (veterinarians, GPs, occupational physicians) is provided, along with support for the rapid exchange of information. This multidisciplinary composition of the group is considered one of the key factors facilitating early recognition. However, a hindering factor in this case is that maintaining a network is time-consuming.

Similarly, an online system called SIGNAAL (Signalering Nieuwe Arbeidsgerelateerde Aandoeningen Loket([32]), operated in Belgium and the Netherlands, allows new cases of diseases to be registered) (see EU-OSHA, 2019a, and Section 3.4.2 for more information on sentinel approaches and their relevance for identifying new cases and potentially emerging risks).

France also has measures to predict flu epidemics. In practice, this means the existence of regional flu observation groups: surveillance conducted by field actors (sentinel practitioners, emergency services, etc.), grouped with the viral surveillance of the Institute Pasteur and pharmaceutical statistics. In addition, a model with premature warning criteria about the duration, intensity and peak of epidemics exists. The facilitating factors of these measures are their quick feedback mechanisms, and scientific publications and popular articles, which ensure credibility. A warning system for emerging risks could be built on such a model and make use of the resources of such an established system.

Response to emerging risks

As is shown in Table 2, the identification of new/emerging (biological) risks is part of the monitoring system for occupational or work-related diseases in only a few of the selected monitoring systems that were evaluated in more detail. Such a system is specified in at least Denmark, France, Germany, and the Netherlands. However, as there is often no system in place to identify new/emerging risks — in which experts are involved to evaluate these (potentially) new risks — let alone initiate an appropriate response if this is considered necessary when new biological risks emerge, these risks could spread quickly.

On the topic of how to respond to emerging risks, three interviewed French experts explained that, in France, mainly institutes of public health are responsible for emerging risk surveillance. The knowledge exists, but the information is not centralised in any specific system. It is fragmented into networks on specific diseases. This makes it difficult to keep the lessons learned from previous situations available. These experts agreed that, although France, like the rest of Europe, has a high level of preparation, this will not be sufficient in the event of a pandemic. Implementing a national preparation and information system, and adding a more organisational structure, on both a national and a European/international level, would be an improvement. The experts emphasised that a specific system should be assigned to emerging risks so that, when indicators of an emerging risk arise, an assessment can be initiated quickly, in the form of small-scale research on what the risk is, and this can then be reported.

Generally, the Danish experts felt that it would be interesting to carry out epidemiological studies in the field of biological environmental work in order to map this issue, using, for instance, the long and detailed records that already exist in Denmark. It would also be helpful to have threshold levels for microorganisms that could be used during workplace risk assessments. To illustrate this, during the focus group discussions, the experts explained how it was difficult to pinpoint the exact biological agents in certain work environments that pose a wide variety of (biological) risks to workers; this makes it even more difficult to implement the necessary preventive measures. As examples, they mentioned organic dust in waste treatment facilities and a variety of biological agents in sewage systems. For risks involving chemicals, radiation and vibration, several workplace risk assessment methods already exist. However, for biological agents it is difficult to obtain a complete overview of the risks because no specific methods are available.

[32] www.signaal.info

According to the experts, future actions should emphasise the importance of developing evaluation criteria that are relevant to the practitioner, and that supervisors and employers can use as a tool to evaluate and assess risks on site.

From the stakeholder workshop, it became clear that data from monitoring systems could also be made available/harmonised for risk assessment purposes by means of a job exposure matrix.

From the interviews, it became clear that policy measures at the national level are mainly influenced by the press, politics (e.g. a minister or opposition party), professional organisations (e.g. research institutes and occupational health authorities), lobbying groups and newly emerging situations. The experts felt that they were, to some extent, able to influence the topics on a national level by cooperating with national institutes and reporting emerging situations. The sectors, occupations and developments that the experts identified as needing more national attention were animal-related occupations, agriculture, forestry, horticulture, nature or the environment, the (bio-)waste industry, recycling, professionals in contact with the public, the effects of climate change, travel and trade, and negative beliefs regarding vaccination.

3.4.3 Emerging risks in sectors of concern

The experts interviewed for this review described different neglected occupational areas or emerging problems with biological agents at work, such as nanotechnology, green fields and personally transferred viral infections. Sectors and occupations that the experts identified as needing more national attention were:

- the bio-economy as a whole, which still lacks up-to-date information on different work settings;
- agriculture (high incidence);
- the food industry, because of new foods and new ways of producing food (e.g. fibrising proteins to resemble meat, such as in Quorn);
- animal husbandry and production (poultry);
- wood processing;
- waste management, recycling and cleaning work;
- rescue services and police officers (accidental exposure).

The focus group discussions identified the emerging risks in three selected sectors. The experts also talked about several specific trends and developments leading to emerging risks of exposure to biological agents. New viruses (especially respiratory agents) affecting farmers and agricultural workers were flagged by experts from three countries in the focus groups. The experts also flagged the observation that the working population is becoming more vulnerable to biological agents, the risks posed by multi-resistant/omni-resistant microbes, and new risks due to the circular economy and the greening of the economy, the use of new materials and the increasing average age of the working population. Several countries have measures in place to prevent the occurrence of these risks. Based on the outcomes of the stakeholders' workshop (task 4), other occupations affected by emerging risks include people working with migrants/refugees, home care workers and workers in green jobs.

A detailed description of the risks and the emerging issues identified by the experts as well as examples of the preventive programmes in place are given in Sections 3.1 and 3.2 of the review.

3.5 Monitoring systems

Occupational disease and/or occupational exposure monitoring systems include a wide range of systems, for example registration systems, information systems, surveillance systems and classification systems. Data can be registered in, for example, (online) databases and sentinel systems. The monitoring systems that operate in European countries differ greatly in the type of information that is registered, which diseases related to exposure to biological agents are registered, how exposure to biological agents (e.g. as a cause of disease) is incorporated into these systems and the way in which the output from these systems is made available.

As is described in Section 2.1, based on the responses to the questionnaire survey for the literature survey, several monitoring systems were evaluated in more detail, to see, for example, how work-related

diseases are registered within the different systems and the type of data that could be extracted from the systems. One of the objectives of this data extraction was to obtain an idea of which type of work-related diseases related to biological agents have been registered in, for instance, different sectors, as well as to determine the occurrence of (registered) exposures to biological agents.

3.5.1 Monitoring systems for work-related diseases

An occupational disease is defined as any disease contracted primarily as a result of exposure to risk factors arising from work activity, whereas a work-related disease can have multiple causes, and work environment factors may play a role, together with other risk factors, in the development of such diseases. A 'recognised case of occupational disease' is a case accepted as such by a competent national authority in an administrative procedure.

Owing to the general lack of knowledge and awareness of exposures to biological agents and the related health problems identified in this review, the characterisation of work-related health effects caused by biological agents is often considered difficult, since the cause of the disease cannot always be directly related to the work environment. Whether or not an exposure occurs and a disease is caused may depend on a multiplicity of factors that are not easy to trace and relate to each other.

As part of the literature review (task 1), a questionnaire was distributed to collect information about, for example, monitoring systems (see Section 2.1). The questionnaire respondents reported on the systems at the national level and indicated that the information collected by the systems is generally used as an input for policy-making, prevention programmes or research. They also said it was used to a lesser extent as an input for disease surveillance, to keep track of the prevalence and incidence rates of diseases, for warning and control systems and inspections, or for compensation, educational purposes, enforcement, and diagnostics or cures.

The responses to the questionnaire and the analysis of the monitoring systems indicated that diseases due to biological agents are generally reported in generic occupational disease-recording systems that do not specifically focus on biological agents. However, there are a few exceptions, such as specific systems in the healthcare sector and systems for compulsory reporting under public health provisions (e.g. for hepatitis and tuberculosis). The number of systems mentioned by the respondents in the questionnaire survey that registered occupational or work-related diseases related to biological agents was limited, and mostly focused on the registration of infectious diseases and occupational accidents or injuries, probably linked to needlestick injuries. The systems may be used to provide categorised data on occupational diseases, information for inspections that is easily accessible, and information for surveillance studies (for example information on blood-borne pathologies among healthcare workers) or may be focusing on a specific work-related disease (i.e. legionnaires' disease, brucellosis and MRSA).

The information provided by the respondents was also helpful for selecting the systems that were analysed and are described in this chapter, and also done so in more detail in the literature review, in which detailed data extracted from the systems are also included (EU-OSHA, 2019a).

Results from scientific literature

The scientific literature analysed for this review mainly covers systems related to monitoring occupational diseases, such as the French RNV3P system, and the German and Taiwanese systems related to national health insurance (including compensation for occupational diseases). Furthermore, specific topics such as occupational asthma, blood-borne diseases among healthcare workers and, to a lesser extent, STIs among sex workers are mentioned. In many instances in the literature, the descriptions available of biological agents are more general.

Broadly speaking, the available databases that are described in the literature can be sorted into two groups: large-scale (national) surveillance (RNV3P), and small-scale databases set up by, for example, singular clinics, hospitals, companies and humanitarian initiatives. However, both groups are under-represented in the scientific literature, possibly because such databases are rarely published in scientific journals.

Results from the stakeholder workshop

During the stakeholder workshop (task 4), participants also discussed the monitoring of diseases. The main topics discussed were the differences and similarities between Member States' systems and approaches, the challenges of gathering exposure data (e.g. exposure measurements, quality of data), the harmonisation of the definition of biological agents and cooperation between the areas of occupational health and public health. The full group discussion summary can be found on the EU OSHA website (EU-OSHA, 2018a). Some results are incorporated into the following sections discussing the monitoring systems and their use and potential, and contrasting them with the needs identified and views gathered through the qualitative research with experts and workplace practitioners (tasks 2 and 3).

The harmonisation of the definition and classification of biological agents was considered a necessity. This could be facilitated if there were one database for/used by all Member States. This would also facilitate the sharing of data. Currently, Eurostat is reviewing a list of biological agents. Eurostat is applying a new approach, which links occupational diseases to biological agents if possible, and this is believed to stimulate harmonisation. Furthermore, information leaflets for biological agents could be developed, based on the concept of safety data sheets. These documents would also facilitate the harmonisation of the definition of biological agents.

Cooperation between the areas of occupational health and public health would be beneficial, as public health has experience of sentinel systems for infectious or chronic diseases, and occupational health has valuable knowledge of exposure. It would also be beneficial if the registration and monitoring of occupational exposure and diseases were integrated into public health.

It is difficult to establish a link between disease and workplace exposure when carrying out a certain task. To solve this issue, and to be able to collect this type of information, it is very important that GPs are involved in the monitoring system that links occupational exposure to biological agents to disease, as this will make sure that this type of information is also 'captured' by the system.

3.5.2 Monitoring of occupational diseases across Europe

The section below presents a short description of the monitoring systems selected from six European countries (Denmark, Finland, France, Germany, the Netherlands, and the United Kingdom). Furthermore, some of the similarities, differences, benefits and limitations of the monitoring systems operating in these European countries, of which an overview is also presented in Table 2, are described. More details on these systems as well as on the data that have been extracted for each of these systems can be obtained from the literature review (EU-OSHA, 2019a).

Registration of occupational diseases in the Netherlands

As prescribed in the Working Conditions Act and the Working Conditions Regulation, occupational physicians (company doctors) or certified health and safety service providers are obliged to notify occupational diseases to the Dutch Centre for Occupational Diseases (Nederlands Centrum voor Beroepsziekten, NCvB). This obligation, in principle, covers all occupational diseases and all sectors. An occupational disease is defined as a disease or condition resulting from an exposure that has occurred predominantly in an occupational situation. A suspicion of occupational diseases can also be notified. This notification duty includes the aggravation of existing diseases, and diseases that have manifested themselves during a previous job or in previous employment. The registration of occupational diseases is not linked to workers' compensation; the NCvB registers and reports occupational diseases via the national notification and registration system (based on reports from occupational physicians), and three specific surveillance projects that register reports of occupational skin diseases by dermatologists (the ADS project), occupational lung diseases by lung specialists and cases of chronic toxic encephalopathy by the two solvent teams operating in the Netherlands. The main purpose of these registrations is to improve knowledge of and insight into the occurrence and prevention of occupational diseases. A notification of an occupational disease should at least contain information on:

1. diagnosis:
   - diagnosis/clinical description, based on a coding system with fixed categories (Classification for Health and Safety and Social Insurance — Classificatie voor Arbo en Sociale verzekering, CAS — codes) and a detailed description of the disorder/disease;
   - cause/exposure, based on a coding system with fixed categories of work-related factors taken from a European list of causes, and a detailed description of the cause of the exposure, with the possibility of distinguishing between the main cause/exposure and one or two other causes/exposures, the categories for biological agents being the following (since 1 January 2016):
     - bacteria — *Leptospira*
     - bacteria — *Mycobacterium*
     - bacteria — *Rickettsia*
     - bacteria — *Salmonella*
     - bacteria — *Staphylococcus aureus*
     - bacteria — *Streptococcus*
     - bacteria — other
     - viruses — hepatitis A virus — picornaviruses
     - viruses — hepatitis B virus
     - viruses — hepatitis C virus
     - viruses — hepatitis E virus
     - viruses — hepatitis virus (others)
     - viruses — HIV (Human immunodeficiency virus, AIDS virus)
     - viruses — other
     - parasites
     - fungi — *Aspergillus fumigatus*
     - fungi — *Candida albicans*

- fungi — *Trichophyton*
- fungi — other
- plants/vegetable-based products
- animals — insects
- animals — mites
- animals — ticks/harvest mites (ixodes)
- animals — birds
- animals — mammals
- animals — other
- other biological agents;

2. the worker's gender and year of birth;
3. the nature and extent of stress(or) at work/as part of working conditions;
4. the nature of work when occupational disease manifested/emerged, for example:
    - occupation/job, based on a coding system (the International Standard Classification of Occupations (ISCO), ISCO-08) and a detailed description of the occupation/job;
    - economic sector/industry, based on the coding system (the Standard Business Indicator (SBI) codes of the Central Bureau of Statistics and a detailed description of the company;
5. the worker's profession at time of exposure;
6. the worker's economic activity at time of exposure.

The report also provides the possibility of including some information on what advice has been given (to the employer and/or the worker), and/or which control measures have been implemented and who has been informed of the occupational disease. This at least facilitates the possibility of linking the occupational disease report to action on prevention and a follow-up on such information.

Guidance and information notices are available to the occupational physician. Furthermore, the NCvB has a helpdesk that can be contacted, and one of the NCvB team members specialises in biological agents and related diseases.

Each year, key figures concerning registration are published (in Dutch) by the NCvB by order of the Ministry of Social Affairs and Employment. These reports give an overview of the number and nature of registered occupational diseases, and their distribution over sectors and occupations in the Netherlands. They also present some information on scientific and social developments with regard to occupational diseases. Apart from the reports on key figures described above, which are also promoted by means of newsletters, the NCvB reports on an annual basis to health and safety services, independent occupational physicians and Eurostat. The data are also publicly available: anyone has been able to generate statistics from the digital database for several parameters (such as diagnosis, cause, economic sectors and occupations) since 1997. However, these statistics are generally presented at the level of larger categories (e.g. the categories bacteria/viruses/parasites/fungi as causes), and thus little detail is given. Furthermore, statistics can be generated for only one or two parameters at the same time, and the output is for a maximum of 5 consecutive years.

Based on the 2011-2015 figures from the publicly accessible database, the highest number of registered occupational diseases related to exposure to biological agents occurred in healthcare workers (caregivers). The numbers of registered occupational diseases due to biological agents as a percentage of the total numbers of registered occupational diseases were highest among trained foresters, fishermen and hunters (51.4 %), farmers, cattle breeders, fishermen, and other hunters and gatherers (32.1 %), food-processing workers (28.1 %), trained farmers (18.1 %) and soldiers in the army (17.3 %). Furthermore, no clear pattern in the diseases in the different occupations

could be observed. Although the proportions of registered occupational diseases due to biological agents seemed to be a little higher in the age categories below 21 years and 21-30 years, the absolute numbers of registered occupational diseases were low in these categories (EU-OSHA, 2019a). These findings confirm those in the literature review and experts' view of the most affected sectors. They also confirm that it is particularly important to protect vulnerable workers such as young workers.

Of the occupational diseases linked to biological agents exposure, most were skin conditions (such as fungal infections, inflammation, allergies or irritated skin condition due to biological agents, parasites and scabies), airway symptoms (asthma — allergic, fungi-related; influenza A; pneumonia; allergic rhinitis; chronic bronchitis; others — infections, allergies), intestinal infections (such as those caused by norovirus, *Campylobacter* and *Salmonella*), Lyme disease, tuberculosis, zoonoses such as leptospirosis, and travel-related conditions (*Shigella* infections, dengue fever, chikungunya, giardiasis, parasite infection, rickettsioses). There were also cases of malaria, Q fever, and childhood diseases such as pertussis and measles. The literature review provides more detailed results from the system. An overview of the most relevant diseases confirms the issues highlighted by the experts, namely the importance of zoonoses, travel-related diseases and skin conditions due to exposure to biological agents, and the increasing importance of non-endemic diseases due to travelling or transport activities.

Registration of occupational diseases in the United Kingdom

Several systems for registering occupational diseases are in operation in the United Kingdom; these are described below.

HSE publishes a range of statistics relating to health and safety in the United Kingdom. Using a variety of data sources, including surveys and surveillance schemes, it provides statistics on:

- work-related ill health and disease;
- workplace injury;
- enforcement of health and safety legislation;
- working days lost and costs to the United Kingdom as a result of health and safety incidents;
- working conditions and management of health and safety in the workplace.

HSE runs most of the registration systems and is also responsible for (or at least involved in) the statistical evaluation of the data. In addition to the annual generic overviews published by the HSE, the Health and Safety Statistics tables, which are publicly available, are also specifically generated for each of the systems on an individual basis.

Reporting of Injuries, Diseases and Dangerous Occurrences Regulations

The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) require employers, the self-employed and people in control of premises to report certain incidents (deaths, injuries, occupational diseases and dangerous occurrences) to the authorities. It is a legal requirement that allows the enforcing authorities to target their work and provide advice on how to avoid work-related deaths, injuries, ill health and accidental loss.

As part of RIDDOR, employers and self-employed people must report the diagnoses of certain occupational diseases, when these are likely to have been caused or made worse by their work. A reportable disease must be diagnosed by a doctor. Diagnosis includes identifying any new symptoms, or any significant worsening of existing symptoms. Workers must provide their employer with the diagnosis in writing. Of the eight reportable occupational diseases, occupational dermatitis, occupational asthma and disease or acute illness caused by occupational exposure to biological agents are relevant to biological agents. With regard to the third of those, healthcare work and laboratory work are considered key risk occupations, and specific infections mentioned are anthrax, zoonoses, BSE, influenza, legionellosis and SARS (HSE, 2019). Although RIDDOR places a requirement on employers to report prescribed occupational diseases, such reports are few. In addition, any accident or incident that results or could have resulted in the release or escape of a biological agent likely to cause severe human infection or illness (caused by biological agents in Risk Groups 3 and 4) should be reported.

The Labour Force Survey

HSE commissions annual questions in the Labour Force Survey (LFS) to gain a view of work-related illness and workplace injury based on individuals' perceptions. The LFS is a large nationally representative survey of households at private addresses in the United Kingdom, currently consisting of around 41,000 responding households each quarter. The HSE questions are included in two survey modules, the 'Workplace Injury' survey module and the 'Self-reported Work-related Illness (SWI)' survey module. The Workplace Injury survey module gives annual estimates of the levels of workplace injury by a range of demographic and employment-related variables and complements the flow of non-fatal injury reports made by employers and others under RIDDOR. The SWI survey module provides an indication of the annual prevalence (including longstanding as well as new cases) and incidence (new cases) of work-related illness and its distribution by major disease group and a range of demographic and employment-related variables. It captures the most widely based definition of work-related ill health. Because individuals are asked to self-report any work-related illness that they believe to have suffered in the previous 12 months, responses obviously depend on laypeople's perceptions of medical matters.

Voluntary reporting of occupational diseases by GPs

THOR-GP is a surveillance scheme in which GPs are asked to report new cases of work-related ill health. Participating physicians report anonymised information on newly diagnosed cases to the Centre for Occupational and Environmental Health (COEH) at Manchester University. The pool of voluntary reporters currently participating in this project consists of around 250 trained GPs. The reporters are instructed to make decisions on whether or not a new case should be identified as being attributable to work on the basis of the balance of probabilities (i.e. whether it is more likely than not).

Voluntary reporting of work-related ill health by specialist doctors

The Health and Occupation Reporting Network (THOR) is a voluntary surveillance scheme for work-related ill health. As members of this network, specialist doctors systematically report all new cases that they see in their clinics. These reports are collated and analysed by a multidisciplinary team at the COEH at Manchester University. The THOR network currently consists of two specialist reporting schemes. These are SWORD (Surveillance of Work-related and Occupational Respiratory Disease, based on reports from hospital consultants specialising in respiratory disease) and EPIDERM (an occupational skin disease surveillance scheme, based on reports from consultant dermatologists). Like the THOR-GP scheme, it consists of a sampling process whereby most participating doctors are asked to send in reports for 1 month of each year, and the numbers of cases that they report are multiplied by 12 to obtain the estimated annual totals.

The main categories of the work-related respiratory diseases reported by consultant chest physicians to SWORD include:

- allergic alveolitis;
- asthma;
- bronchitis/emphysema;
- infectious diseases;
- inhalation accidents;
- benign pleural disease;
- malignant mesothelioma;
- lung cancer;
- pneumoconiosis;
- other respiratory illness.

The main categories of the skin diseases reported by consultant dermatologists to EPIDERM include:

- contact dermatitis;
- contact urticaria;
- folliculitis/acne;
- infective skin disease;
- mechanical skin disease;

- nail conditions;
- skin neoplasia;
- other dermatoses.

The annual incidence of work-related ill health reported in THOR is estimated on the basis of cases reported by the participating physicians, who report cases either each month (core reporting) or on one randomly assigned month per year (sample reporting). Cases reported by sample reporters are multiplied by 12 and added to the cases reported by core reporters to obtain an annual estimated total of cases reported by all reporters. In 2014, consultant chest physicians reported about 1,551 estimated new cases of respiratory diseases to SWORD, and dermatologists reported about 1,320 estimated cases of skin diseases to EPIDERM.

Ill health assessed for disablement benefit

Industrial Injuries Disablement Benefit (IIDB) is for people who are disabled because of an accident at work or who have certain diseases caused by their work (but not in cases of self-employment). There are no age rules, but the worker must have a contract of employment. The law provides for payment of benefits to people who are suffering from certain diseases (called 'prescribed diseases') contracted in the course of certain types of employment or while working on an approved employment training scheme or course. Diseases or injuries are prescribed where an occupational cause is well established, and when they are of genuine occupational origin (i.e. the risk is not common to everybody). There is no entitlement to compensation in respect of a disease if it is not listed as a prescribed disease, or if the person's job is not listed against the specific disease. However, the worker may be entitled to compensation under the industrial accident provisions if the disease has been caused by an accident. For most diseases, compensation is payable if the extent of disability is assessed as 14 % or more. IIDB statistics are available annually from 2003 onwards, but earlier historical data are also available.

Table 1 lists prescribed diseases with a biological cause.

Table 1: Overview of prescribed diseases with a biological cause covered by IIDB in the United Kingdom

Name of disease or injury Conditions due to biological agents (caused by an animal, plant or other living organism)	Type of job Any job involving:
Cutaneous anthrax; pulmonary anthrax	(a) Contact with anthrax spores, including contact with animals infected by anthrax; or (b) handling, loading, unloading or transport of animals of a type susceptible to infection with anthrax or of the products or residues of such animals.
Glanders	Contact with equine animals or their carcasses. For example, farm and slaughterhouse workers, and grooms handling horses.
Infection by *Leptospira*; for example, swamp fever, swineherd's disease and Weil's disease	(a) Work in places that are, or are liable to be, infested by rats, field mice or voles, or other small mammals; or (b) work at dog kennels or the care or handling of dogs; or (c) contact with bovine animals or their meat products or pigs or their meat products.
(a) Cutaneous larva migrans;	Contact with a source of ankylostomiasis.

Name of disease or injury **Conditions due to biological agents (caused by an animal, plant or other living organism)**	**Type of job** **Any job involving:**
(b) Iron deficiency anaemia caused by gastrointestinal infection by hookworm	
Tuberculosis	Contact with a source of tuberculosis while undertaking: (a) work in a hospital, a mortuary in which post-mortems are conducted or a laboratory; (b) work in any other workplace.
Extrinsic allergic alveolitis (including farmer's lung)	Exposure to moulds or fungal spores or heterologous proteins or any other biological substance that causes extrinsic allergic alveolitis for reasons of employment in: (a) agriculture, horticulture, forestry, cultivation of edible fungi or malt-working; (b) loading or unloading or handling in storage mouldy vegetable matter or edible fungi. Any occupation involving: (c) caring for or handling birds; (d) handling bagasse; (e) work involving exposure to metalworking fluid mists; (f) any other workplace.
Infection by organisms of the genus *Brucella*	Contact with: (a) animals infected by *Brucella*, or their carcases or parts thereof, or their untreated products; (b) laboratory specimens or vaccines of, or containing, *Brucella*. For example, farm, veterinary, slaughterhouse and animal laboratory workers.
Infection by hepatitis A virus	Contact with raw sewage.
Infection by hepatitis B or C virus	Contact with: (a) human blood or human blood products; (b) any other source of hepatitis B or C virus.
Infection by *Streptococcus suis* (a very rare form of meningitis from exposure to infected pigs or pork products)	Contact with pigs infected by *Streptococcus suis*, or with the carcasses, products or residues of pigs so infected. For example, pork butchers, pig breeders and slaughterhouse workers.
Avian chlamydiosis	Contact with birds infected with *Chlamydia psittaci*, or with the remains or untreated products of such birds. For example, duck farm workers, feather-processing workers,

Name of disease or injury Conditions due to biological agents (caused by an animal, plant or other living organism)	Type of job Any job involving:
	abattoir workers, poultry meat inspectors, and pet shop owners and assistants.
Ovine chlamydiosis	Contact with sheep infected with *Chlamydia psittaci*, or with the remains or untreated products of such sheep. For example, sheep farm workers and veterinary surgeons.
Q fever	Contact with animals, their remains or their untreated products. For example, farm workers involved in the rearing of sheep, abattoir workers and veterinary surgeons.
Orf	Contact with sheep or goats, or with the carcasses of sheep or goats. For example, farm workers, abattoir workers and meat inspectors.
Hydatidosis	Contact with dogs. For example, shepherds, veterinarians and people who care for dogs.
Lyme disease	Exposure to deer or other mammals of a type liable to harbour ticks harbouring *Borrelia* bacteria.
Anaphylaxis	Contact with products made with natural rubber latex.

Source: https://www.gov.uk/government/publications/industrial-injuries-disablement-benefits-technical-guidance/industrial-injuries-disablement-benefits-technical-guidance#appendix-1-list-of-diseases-covered-by-industrial-injuries-disablement-benefit (website visited December 2018).

The table is quite illustrative of the type of disease liable for compensation and the type of work related to the disease. It confirms the findings of the literature review on the importance of addressing biological agents in animal-related professions and farming, as well as the prevalence of zoonoses; the importance of blood-borne viruses in the healthcare sector; and the importance of re-emerging diseases such as tuberculosis and Q fever. However, it also demonstrates that it is difficult to trace respiratory diseases and allergies to specific biological agents; therefore, the importance of biological agents and prevention measures covering them, as well as their contribution to these diseases, may be overlooked.

Registration of occupational diseases in Germany

Occupational diseases are monitored in Germany by physicians and dentists, who are legally obliged to notify the responsible employer's liability insurance association or the state authority responsible for OSH of cases and suspected cases of occupational diseases. Everyone, including workers, may seek medical advice when feeling unwell or when ill. Any physician or dentist has the right and obligation to evaluate the diagnosis and, if appropriate, make a notification to the DGUV. The duty of notification of the doctor is independent of the patient's consent or dissent, with a few exceptions. Importantly, the notification of an occupational disease by a physician does not violate the physician's obligation to medical confidentiality.

Furthermore, workers themselves may report suspected occupational diseases. Employers are also obliged to report suspected occupational diseases, and this duty is independent of the duty of physicians to submit notifications of occupational diseases. Upon notification, the responsible employer's liability insurance association contacts the affected worker for clarification of relevant case data. The notified suspected case is evaluated by responsible experts at the employer's liability insurance association on the basis of the medical diagnosis and the occupational and private circumstances of the individual, and is either accepted or rejected as an occupational disease. The course of the disease is jointly evaluated by the worker and the employer's liability insurance association, taking into account relevant workplace conditions. Further medical assessments may be requested. These experts evaluate the case and, if appropriate, have to consult with the diagnosing physician, the worker and the employer. When diseases arise that are independent of occupational activity, the costs associated with treatment and compensation are covered by statutory health insurance or private health insurance. When diseases arise from occupational activity, the costs associated with treatment and compensation are covered by the DGUV.

Occupational diseases are defined as diseases that, according to knowledge available in medical science, occur among individuals who, due to their occupational activity, experience a specific illness at a noticeably higher level than those of the overall population. As of 22 December 2014, the list of occupational diseases comprised 77 recognised occupational diseases. The basic classification is by aetiology. Some of these occupational diseases can be caused or aggravated by biological agents:

Occupational infectious diseases:

- 3101: infections in the healthcare and welfare sectors;
- 3102: zoonoses;
- 3103: worm infections among miners (*Ankylostoma duodenale* or *Strongyloides stercoralis*);
- 3104: tropical infections, typhus.

Occupational diseases from organic dusts:

- 4201: exogen-allergic alveolitis;
- 4202: diseases of the lower respiratory tract and lungs from raw cotton, flax or hemp fibre (byssinosis);
- 4203: adenocarcinomas of nasal cavities from oak or beech wood dust;
- 4301: respiratory diseases due to sensitising agents, including rhinopathy that causes the cessation of all activities that may provoke manifestation or recurrence of the disease
- 4302: respiratory diseases due to chemically irritating or toxic agents, which need all activities that may provoke the manifestation or recurrence of the disease to cease.

Skin disease:

- 5101: severe or recurrent skin disorders, which cause the cessation of all activities that may provoke manifestation or recurrence of the disease.

The German classification system for occupational diseases is similar, to some degree, to the WHO International Classification of Diseases (ICD), 10th revision (ICD-10) ([33]), which also has categories based on topology and aetiology, and moreover pathology, for example in the case of airway diseases. The DGUV provides bulletins on individual occupational diseases, which contain information on incidence, potential sources of risk, trends and the course of the disease (BAuA, 2016). Bulletins are available for all occupational diseases that involve or may involve biological agents, namely for occupational infections (3101 to 3104), for respiratory disorders (4201 to 4203), for obstructive respiratory diseases caused by organic dust (4301, 4302) and for skin diseases (5101).

Publications are provided on an annual basis by the DGUV, and present detailed statistics on the workforce of the country and the occurrence of accidents and diseases due to occupational activity (including travelling to the workplace). Furthermore, the annual *Safety and health at work* (Sicherheit und Gesundheit bei der Arbeit — SUGA) reports (BMAS/BAuA, 2020 and other years) provide a statistical overview of OSH. These reports contain tables that provide data on disease groups (e.g. of the respiratory tract, of the skin, of the musculoskeletal system) by industry sector. In addition, there are individual publications on, for example, the epidemiology of occupational infections (Fischer et al., 2013) and occupational infections in the healthcare sector (Dulon et al., 2015).

In 2018, there were 82,622 notifications of suspected cases of occupational disease, and 40,096 were recognised as occupational diseases. With regard to infectious diseases, in 2018, there were 3,141 notified suspected diseases, 1,720 of which were recognised cases of occupational disease and 26 were fatalities. With regard to respiratory disorders caused by organic dust and obstructive airway diseases, there were 3,557 notified suspected diseases (of which 362 were caused by organic dust), 640 recognised cases of occupational disease (of which 111 were caused by organic dust) and 89 fatalities (of which 22 were caused by organic dust) (BMAS/BAuA, 2020). Diseases caused by organic dust include diseases caused by cotton and wood dust.

In addition, in March 2014, a revised code of practice, TRBA 250 on needlestick injuries, was released (ABAS/BAuA, 2014). The healthcare sector is one of the most important and most affected sectors with regard to occupational infections, with 927 notified suspected occupationally acquired infections in 2014 (Dulon et al., 2015).

The data, especially on organic dust-related diseases, confirm the importance of the issue and the importance of the prevention of exposures highlighted by the experts, in particular with regard to complex dust mixtures and the allergenic effects of these exposures to biological agents. It is important, as pointed out by many experts, to focus on the prevention of allergenic effects and dust exposure, and experiences from the area of chemical exposures could help serve this goal. In Germany, the two advisory bodies responsible for chemical (AGS) and biological agents (ABAS) work closely together, as already explained earlier in this review, and this example could be followed by other countries.

Use of health surveillance data

The process of evaluation also includes health examinations for preventive worker health surveillance. Periodic health examinations are obligatory for workers exposed to hazardous substances. The following types of health examination are conducted, depending on the type of exposure and the individual situation of the worker:

- pre-employment health examinations;
- health examinations for workers in hazardous jobs, including examination for pathogens (e.g. in health care);
- health examinations after long periods of sick leave;
- continuous health examinations to assess work ability;
- health examinations after retirement from hazardous jobs such as asbestos work.

([33]) The International List of Causes of Death was adopted by the International Statistical Institute in 1893. WHO has been entrusted with the ICD since its creation in 1948. The ICD is the international standard for reporting diseases and health conditions. It is the diagnostic classification standard for all clinical and research purposes. The ICD defines the universe of diseases, disorders, injuries and other related health conditions in a comprehensive, hierarchical fashion.

These preventive health examinations in the context of occupational activity may be either facultative or mandatory, depending on the professional activity (type of work) and the underlying legal provisions. With regard to biological agents, the mandatory health examinations that are in place include the protection of individuals not involved in the actual occupational activity. This is particularly relevant in health care and has been laid down in the Law on Protection against Infections (Infektionsschutzgesetz).

Registration of occupational diseases in France

RNV3P

The French network RNV3P was created in 2001 on a voluntary basis in collaboration with some occupational disease clinics (ODCs). In 2007, ANSES began to coordinate the network. Since 2008, it has been obligatory to record all consultations in ODCs, in accordance with the convention between ANSES and each teaching hospital. Since 2016, RNV3P has brought together all the 31 ODCs in mainland France and 9 OSH service centres related to the network. The network system provides records of all consultations carried out in the ODCs and all occupational health problems diagnosed by the OSH services participating in RNV3P (including demographic data, diseases, exposures, industry sectors, professions, causality between diseases and exposures) in a standardised way. Occupational physicians, other clinical experts and their staff record the data in the system network. The main objectives of the RNV3P network are to:

- identify and describe OSH risk situations in France;
- investigate new aetiologies and emerging risks;
- improve and harmonise diagnostic practices in relation to work-related diseases.

The RNV3P network is thus a network of experts in the field of occupational diseases (universities, practitioners, institutional experts sharing information via working groups, committees and other forms of information exchange) and a health database containing information on diseases and occupational exposure at the same time.

For inclusion in the national RNV3P database, data are recorded according to the following (international) standards:

- **Diseases:** ICD-10.
- **Occupations:** ISCO-08. Between 2001 and 2013, the 1988 version was used. Since 2014, the new information system has used the 2008 version.
- **Industry sectors:** French Classification of Activities (NAF-08). Between 2001 and 2013, the 1993 version was used. Since 2014, the new information system has used the 2008 version.
- **Occupational exposures:** French Thesaurus of Occupational Exposures (TOE), a dedicated classification (a modified version of the European Classification of Causal Agents of Occupational Diseases).

The ‘Beta-2’ version of TOE contains more than 8,000 labels and is divided into two parts:

- substances and agents, with six categories (chemical agents, biological agents, stone and mineral substances, physical agents, biomechanical factors, and organisational and managerial factors);
- context of use and industrial process.

About 3,000 out of the over 8,000 labels are related to biological agents, which are divided into the following categories: microorganisms (bacteria, viruses, fungi and parasites), animals (invertebrates and vertebrates) and plant material. The TOE does not provide information on exposure levels but does provide an assessment of work-relatedness (in which the attribution of exposure in the workplace to the overall relationship between exposure and disease is rated by clinical experts).

ANSES provides an annual activity report based on the data collected by the network, which is available on its website. Information on RNV3P, including its database, is directly available to all the network’s partners via a secured website. Anyone outside the network can also access the data by submitting a request to ANSES.

One of the main objectives of RNV3P is to identify emerging occupational risks. This is done through the Emergence Working Group, which validates clinical case reports from ODCs using data mining and specific searches (in the literature, case studies reported by NIOSH and information from the European Modernet Network). In addition to acquiring expertise, the aim of this working group is to make information available for prevention. Therefore, information on these case reports is disseminated to the RNV3P network members and prevention stakeholders (through internal processes, external publication, etc.).

Examples of reports that were related to exposure to biological agents are reported in Section 3.5.2 for new and emerging risks

Registration of recognised occupational diseases in France

In France, compensation for accidents at work and (recognised) occupational diseases is paid by the local health insurance fund (in metropolitan France) or the General Social Security (in the overseas departments). French law classifies occupational diseases itemised on a special list of 98 diseases in the same category as accidents at work because they are work related (INRS, 2019). Of these 98, 24 occupational diseases are related to exposure to biological agents:

- occupational tetanus;
- anthrax;
- spirochaetoses (leptospirosis, Lyme disease);
- brucellosis;
- ankylostomstomiasis;
- tuberculosis and other mycobacterial infections;
- hepatitis A, B, C, D and E;
- skin mycosis;
- rickettsioses and Q fever
- poliomyelitis;
- infections related to protozoa;
- rabies;
- tularaemia;
- infections related to infectious agents incurred in hospitals and during care at home;
- perionyxes and onyxes (fungal nail lesions);
- viral keratoconjunctivitis;
- pasteurelloses;
- ornithosis/psittacosis;
- swine erysipeloid;
- streptococcus infections;
- hantavirus infections;
- rhinitis and asthma;
- hypersensitivity pneumonitis;
- respiratory diseases caused by/linked to the inhalation of textile fibres.

If the disease is registered in one of the occupational disease tables, and if the relevant criteria to establish a link to work are met, the origin of the disease is presumed to be occupational, and the disease is automatically recognised. Since 1993, it has been possible to report other occupational diseases (i.e. not in the list and/or not meeting the criteria), after which regional committees determine whether or not the reported case is work related/compensable.

The National Health Insurance Fund for Salaried Workers (CNAM-TS) and the Central Fund for Agricultural Mutual Insurance Scheme (CC-MSA) are responsible for the registration of recognised occupational diseases in France. Any accident at work or the occurrence of an occupational disease at work must be reported to the employer within 24 hours. The employer must report the accident or disease to the worker's local health insurance fund within 48 hours and give the worker a special form, which the worker then gives to their doctor. A temporary period of (total or partial) disability starts

immediately after the injury or diagnosis of the disease and ends with the worker's recovery or the healing of the injury. The payment of workplace accident and occupational disease compensation is not contingent on registration with the social security system or the length of the period during which the worker has made contributions. The individual (or their representative) seeking compensation must make a claim to the relevant insurance fund, which will then determine recognition and compensation. This claim is accompanied by a medical certificate describing the disease, from the doctor chosen by the claimant.

More information on the system operated by the CNAM-TS can be found on its website, on which statistics from the database can also be generated. However, the level of detail of the output that can be generated, as well as the level of detail in the available reports, is limited. The proportion of recognised diseases related to biological agents is low compared with the total number of recognised diseases. Those most prominently represented are tuberculosis and other mycobacterial infections, infections related to infectious agents encountered in hospitals and during care at home, rhinitis and asthma. Figures were higher for rickettsioses and Q fever in 2016; the latest year for which statistics were available is 2018 (CNAM/DRP, 2020).

Regarding agriculture, the CC-MSA does not provide information on the number of reported cases or other statistics. The CC-MSA is primarily responsible for occupational risk prevention among agricultural workers, and can also provide data on compensated occupational diseases for agricultural workers, particularly for workers with direct contact with animals (large animals, small animals and fish farming) and workers in professional hunting and tracking wildlife, zoos, pet shops, etc.

Furthermore, the CC-MSA coordinates a network on surveillance of zoonoses, which consists of the following:

- An observatory: since 2008, this observatory, Zoonoses Surveillance in Agriculture, has allowed doctors working for the CC-MSA to report cases of zoonosis (using standardised reports). These reports provide information that can be used to confirm the diagnosis and the relationship between work and the transmission chain. Each report is validated and is added to a database (which is not publicly available). The statistics from this database are not representative of all French agricultural workers, as they depend on voluntary input from doctors, but a goal of the observatory is to create a qualitative and analytical database on exposure to biological agents. A questionnaire is being developed to improve the observatory.
- One reference couple (an occupational physician and a prevention adviser) for zoonoses in each CC-MSA occupational health service (n = 35).
- A national committee on zoonoses that meets once a year.

- Technical support for the CC-MSA occupational health services network (individual and collective) and agricultural companies.
- The provision of training on zoonoses.
- Some epidemiological studies, publications and prevention documents.
- A serum bank available for research projects (since 2012).

The network was mentioned by experts from France in their contributions to the interviews and focus groups, and could provide valuable information to other initiatives in other Member States, such as FOHS in Finland, the occupational health service for the agricultural sector. FIOH is referred to, for example, in Section 3.1.1 of this report.

Registration of occupational diseases in Denmark

The Danish Working Environmental Authority (DWEA) registers and reports registered and approved occupational diseases and accidents. As prescribed in the Working Conditions Regulation, all physicians (including both GPs and occupational physicians) and dentists are obliged to notify suspected or confirmed occupational diseases to the DWEA and Labour Market Insurance. Labour Market Insurance is responsible for the Danish compensation system for occupational diseases. This notification duty does not explicitly cover the aggravation of an existing disease, but this is also often notified. It does cover occupational diseases that have arisen during a previous job or in previous employment. The employer is obliged to notify the DWEA and Labour Market Insurance of occupational accidents but not occupational diseases. Labour Market Insurance([34]) publishes a list of diseases and associated occupational exposures; the diseases on this list are recognised as occupational diseases and should be notified as such. The following diseases related to biological agents are included in the occupational disease list:

- allergic rhinitis and conjunctivitis;
- allergic alveolitis (including farmer's lung, mushroom worker's lung, bird breeder's lung);
- byssinosis;
- asthma (allergic and non-allergic);
- chronic bronchitis;
- COPD;
- allergic and toxic dermatitis;
- infectious diseases transmitted by animals, humans or the environment (mostly tropical diseases); for example tetanus, ornithosis, Q fever, Weill's disease, tuberculosis, hepatitis, malaria, trypanosomiasis, dengue fever and yellow fever;
- cancer after hepatitis infection.

A notification of an occupational disease should contain the following information:

- diagnosis (ICD-10 code);
- the worker's name and national unique ID number, including birthday and gender;
- the nature and extent of the work or working conditions;
- the nature of the work when the occupational disease manifested;
- the worker's profession at the time of exposure;
- the industry, classified according to DB07, a slightly modified version of the NACE rev 2 classification system, in which the main industry groups are included;
- the worker's job, classified according to the Danish DISCO-88 system of codes, a slightly modified version of ISCO-88, at a two-digit level.

Each region in Denmark has at least one governmental occupational hospital department that employs occupational physicians. Physicians operating in the field can refer to these departments if they are in doubt (in exactly the same way as they refer to other specialist departments, such as cardiology). If a physician suspects that they have encountered a new combination of health effect(s), exposure and

[34] (www.aes.dk)

work situation for which the relationship may not (yet) be well established, this case can be submitted to a committee attached to Labour Market Insurance. This committee then decides if this new combination of health effects and exposure can be recognised as an occupational disease and eventually be included in the list of recognised occupational diseases. Apart from this, there is no alert system for new or emerging occupational risks.

The main purpose of the registration system is the surveillance of risk jobs and industries, including awareness of new risk areas in order to prevent occupational diseases and accidents. Each year information on new registrations is made available on the DWEA website in the form of overview tables, which are broken down by crude diagnostic categories and industry categories (www.at.dk); furthermore, a yearly report is published, and reports with a special focus are also regularly available. For 2004-2009, tables of registered occupational diseases can be created on an electronically available database. For the period after 2009, information made publicly available by means of annual reports provided by the DWEA has to be relied on. The information available in the public database is not specific. For instance, health effects are presented in only eight categories (musculoskeletal disorders, hearing diseases, psychiatric diseases, dermal diseases, respiratory diseases, neurological disorders, cancer, and other and unknown), and no information about specific causes (exposures) is given. One can differentiate on the basis of industry category, job category, gender and age (the latter in 5-year categories). This information, which is also available in the annual reports and statistical overviews provided by the DWEA, provides some details on diseases caused by biological agents but does not, for instance, generally identify the specific biological agent involved.

Other sources

In addition to the DWEA and Labour Market Insurance, the Statens Serum Institut (SSI) also collects some information on occupational infectious diseases and agents. The SSI is an institute operating as part of the (Danish) Ministry of Health, the purpose of which is to prevent and control infectious diseases, congenital disorders and biological threats. All physicians are obliged to notify contagious and serious infectious diseases. Information on the circumstances regarding possible sources of the infection — including occupational sources — must be reported as part of this notification.

Registration of occupational diseases in Finland

FIOH maintains the Finnish Register of Occupational Diseases (FROD). This register contains all new cases notified by insurance companies and the Farmers' Social Insurance Institution (MELA). The recognition of an occupational disease is carried out in a private insurance institution, and the expenses and compensation resulting from a suspected or recognised occupational disease are covered by the private insurance-based system. The employer is obliged to insure the employees for both occupational injuries and occupational diseases. The insurance is voluntary for employers and the self-employed. The Act on Occupational Diseases defines an occupational disease as a disease caused by any physical factor, chemical substance or biological agent encountered in the course of work. In principle, any disease or adverse health outcome that meets the above criteria is liable for compensation, provided that the disease is contracted as a consequence of exposure at work during tasks performed by an employee with a private employer, in the public service or in public office. A part of occupational morbidity, which is not recognised as an occupational disease but is classified as work-related, is not covered by occupational disease compensation. If such a work-related disease outcome results in an inability to work, compensation comes from general disability schemes. There are guidelines for registration.

Diseases caused by biological agents are covered by the system. So far, no special alert system exists with regard to new/emerging risks. There is no specific website for the register. The data are not publicly available and can be analysed only on request, provided that there are sufficient resources. The register contains a wide variety of information concerning cases of occupational diseases, including diagnosis, causal agent, occupation, branch of industry and severity of the disease. Furthermore, the register can provide statistics on disease diagnosis, occupation and branch of industry, and year of reporting. Owing to changes in notification and recognition processes, data from 2005-2013 are not comparable with the previous FROD figures. Occupational disease trends over a longer time period cannot therefore be assessed.

Table 2: Comparison of characteristics of selected occupational disease monitoring systems

Parameter	Country/name										
	Netherlands	United Kingdom					Germany	France		Denmark	Finland
	National notification and registration system	RIDDOR	LFS	THOR-GP	THOR (SWORD/ EPIDERM)	IIDB	Registry of occupational diseases	RNV3P	Registry of recognised occupational diseases	Registry of occupational diseases	FROD ([35])
Operated by	NCvB	HSE	HSE/Office for National Statistics (ONS)	Manchester University COEH ([36])	Manchester University COEH	Department for Work and Pensions Industrial Injuries Benefits Centres	DGUV	ANSES ([37])	CNAM-TS[38] and CC-MSA ([39])	Danish Working Environment Authority (DWEA) and Labour Market Insurance	FIOH ([40])
Website	In Dutch: http://www.beroepsziekten.nl In English: http://www.occupationaldiseases.nl/	http://www.hse.gov.uk/riddor/index.htm	http://www.hse.gov.uk/statistics/sources.htm	http://research.bmh.manchester.ac.uk/epidemiology/COEH/research/thor	http://research.bmh.manchester.ac.uk/epidemiology/COEH/research/thor	https://www.gov.uk/industrial-injuries-disablement-benefit	http://www.dguv.de/medien/formtexte/aerzte/F_6000/F6000.pdf	https://www.RNV3P.fr	http://www.risquesprofessionnels.ameli.fr/statistiques-et-analyse/sinistralite-atmp.htmlhttp://www.ms	https://www.amid.dk/viden-og-forebyggelse/arbejdsskader/erhvervssygdomme/	https://www.ttl.fi/rekisterit/tyoperaisten-sairauksien-rekisteri/

([35]) Finnish Register of Occupational Diseases.
([36]) Centre for Occupational and Environmental Health.
([37]) L'Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail (French Agency for Food, Environmental and Occupational Health and Safety).
([38]) National Health Insurance Fund for Salaried Workers.
([39]) National Health Insurance Fund for Agricultural Workers and Farmers.
([40]) Finnish Institute of Occupational Health.

Parameter	Country/name										
	Netherlands	United Kingdom					Germany	France		Denmark	Finland
	National notification and registration system	RIDDOR	LFS	THOR-GP	THOR (SWORD/ EPIDERM)	IIDB	Registry of occupational diseases	RNV3P	Registry of recognised occupational diseases	Registry of occupational diseases	FROD ([35])
									a.fr/lfr/web/msa		
Type of diseases covered	Work-related diseases or occupational diseases, including suspected cases	Prescribed occupational diseases	Work-related illness	Work-related illness	Work-related illness	Prescribed occupational diseases	Occupa-tional diseases, including recognised occupational diseases	Work-related diseases or occupational diseases	Recognised occupational diseases, but other diseases can also be reported	Work-related diseases or (recognised) occupational diseases	Recognised and suspected cases of occupational diseases
New/emerging risks included	By another system, SIGNAAL: https://www.signaal.info/	Not specified	Not specified	Not specified	Not specified	No	Yes	Yes	No	Yes	No
Part of compensa-tion system for workers	No	Yes	No	No	No	Yes	Yes	No	Yes	Yes	No

Parameter	Country/name										
	Netherlands	United Kingdom					Germany	France		Denmark	Finland
	National notification and registration system	RIDDOR	LFS	THOR-GP	THOR (SWORD/ EPIDERM)	IIDB	Registry of occupational diseases	RNV3P	Registry of recognised occupational diseases	Registry of occupational diseases	FROD [35]
Registration done by	Occupa-tional physicians (or health and safety service providers), other physicians, and through three specific surveillance projects	Employers, the self-employed and people in control of work premises	Individuals (household survey)	GPs	Specialist doctors	Workers	Physicians and dentists, employers and workers	Occupational disease clinics and occupational health services	Workers	All physicians (including GPs and occupational hygienists) and dentists	Employers and insurance companies Data from Worker's Compensa-tion Center and the Farmer's Social Insurance Instition
Mandatory/ voluntary	Mandatory for occupational physicians, voluntary for other physicians	Mandatory	Voluntary	Voluntary	Voluntary	Mandatory	Mandatory for physicians, dentists and employers	Voluntary	Mandatory	Mandatory	Mandatory
All occupational diseases covered	Yes	No	Yes	Yes	No	No	Yes	Yes	Not specified	Yes	Yes

Parameter	Country/name										
	Netherlands	United Kingdom					Germany	France		Denmark	Finland
	National notification and registration system	RIDDOR	LFS	THOR-GP	THOR (SWORD/ EPIDERM)	IIDB	Registry of occupational diseases	RNV3P	Registry of recognised occupational diseases	Registry of occupational diseases	FROD ([35])
All industries covered	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Not specified	Yes	Yes
Registration by means of predefined categories/free-text fields	Both	Both	Not specified	Not specified	Not specified	Not specified	Both	Both	Not specified	Both	Not specified
Coding system for diagnosis/clinical description	CAS codes ([a])	Not specified	Not specified	Not specified	Not specified	System-specific coding system	System-specific coding system ([b])	ICD-10 codes	Not specified	ICD-10 codes	ICD-10 codes
Coding system for occupation/job	ISCO-08	Not specified	Not specified	Not specified	Not specified	Not specified	Not specified	ISCO-08	Not specified	DISCO-88 (a slightly modified version of ISCO-88)	ISCO-08
Coding system for sector/industry	SBI codes	Not specified	Not specified	Not specified	Not specified	Not specified	Not specified	French Classification of	Not specified	DB07 (slightly modified version of	NACE rev. 2

Parameter	Country/name										
	Netherlands	United Kingdom					Germany	France		Denmark	Finland
	National notification and registration system	RIDDOR	LFS	THOR-GP	THOR (SWORD/ EPIDERM)	IIDB	Registry of occupational diseases	RNV3P	Registry of recognised occupational diseases	Registry of occupational diseases	FROD (35)
								Activities (NAF-08)		NACE rev. 2)	
Biological agents included in list of causes/exposures	Yes	Not specified	Not specified	Not specified	Yes	Yes	Yes	Yes	Not specified	Yes	Yes
Guidelines provided for registration process	Yes	Yes	Not applicable	Yes	Yes	Yes	Yes	Yes	Not specified	Yes	Yes
Biological agents covered by guidance	Yes	Not specified	Not applicable	Not specified	Not specified	Not specified	Yes	No	Not specified	Yes	Yes
Training provided for registration process	Not specified	Not specified	Not applicable	Yes	Yes	Not specified	Not specified	Yes	Not specified	Not specified	Not specified
Information from system is used for	Improving knowledge of and	Informing enforcing authorities	Gaining a view of work-related	Surveillance	Surveillance, and investigating	Compensation	Compensation; research,	Identification and description	Compensation	Compensation; surveillance	Obtaining information, research,

Parameter	Country/name										
	Netherlands	United Kingdom					Germany	France		Denmark	Finland
	National notification and registration system	RIDDOR	LFS	THOR-GP	THOR (SWORD/ EPIDERM)	IIDB	Registry of occupational diseases	RNV3P	Registry of recognised occupational diseases	Registry of occupational diseases	FROD (35)
	providing insights into occurrence and prevention of occupational diseases	of risk identification and priorities for investigation, advice and prevention	illness and workplace injury based on individuals' perceptions		increased risk of particular types of ill health in relation to occupations, industries and causal agents or work activities		policy-making and prevention	of OSH risk situations, investigating new aetiologies and emerging risks, and improving and harmonising diagnostic practices in relation to work-related diseases		of risk jobs and industries to prevent occupational diseases and accidents	prevention procedures
Way in which outputs from system are made available	Annual report, including annual statistical report (tables)	Part of annual report by HSE on health and safety in the UK	Part of annual report by HSE on health and safety in the UK	Part of annual report by HSE on health and safety in the UK	Part of annual report by HSE on health and safety in the UK	Part of annual report by HSE on health and safety in the UK	Annual reports and annual statistics	Annual reports (the latest for 2015)	Not specified	Annual reports and annual crude statistics	Annual reports up until 2016

Parameter	Country/name										
	Netherlands	United Kingdom					Germany	France		Denmark	Finland
	National notification and registration system	RIDDOR	LFS	THOR-GP	THOR (SWORD/ EPIDERM)	IIDB	Registry of occupational diseases	RNV3P	Registry of recognised occupational diseases	Registry of occupational diseases	FROD ([35])
Language in which outputs are made available	Dutch, some in English	English	English	English	English	English	German, some in English	French, some in English	French	Danish	Finnish, abstract in English
Website(s) on which outputs are made available	In Dutch: http://www.beroepsziekten.nl/statistiek-introductie; http://www.beroepsziekten.nl/kerncijfers In English: https://www.occupationaldiseases.nl/ncvb/statistics	http://www.hse.gov.uk/statistics/index.htm	http://www.hse.gov.uk/statistics/index.htm	http://www.hse.gov.uk/statistics/index.htm	http://www.hse.gov.uk/statistics/index.htm	http://www.hse.gov.uk/statistics/index.htm	In German: https://www.dguv.de/de/zahlen-fakten/bk-geschehen/index.jsp In English: http://www.dguv.de/en/facts-figures/ods/index.jsp	https://www.anses.fr/fr/content/RNV3P-le-r%C3%A9seau-national-de-vigilance-et-de-pr%C3%A9vention-des-pathologies-professionnelles	CNAM-TS: http://www.risquesprofessionnels.ameli.fr/statistiques-et-analyse/sinistralite-atmp/dossier/nos-statistiques-sur-les-maladies-professionnelles-par-ctn.html CC-MSA: not specified	www.at.dk	Outputs in Finnish, Swedish and English are available at Julkari – publications website https://www.julkari.fi/ , for example https://www.julkari.fi/discover?query=occupational+diseases
Biological agents	Yes	No	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes

Parameter	Country/name										
	Netherlands	United Kingdom					Germany	France		Denmark	Finland
	National notification and registration system	RIDDOR	LFS	THOR-GP	THOR (SWORD/ EPIDERM)	IIDB	Registry of occupational diseases	RNV3P	Registry of recognised occupational diseases	Registry of occupational diseases	FROD (35)
specifically included in data that are made available											
Database publicly available	Yes: https://ncvb.amc.nl/NCVB-MenR	No	No	No	No	No	No	No	CNAM-TS: yes CC-MSA: no	Yes, for the period 2004-2009: https://at.dk/arbejdsmiljoe-i-tal/	No

(a) A conversion table for the translation of CAS codes into ICD-10 codes and vice versa is available.

(b) The German classification system for occupational diseases is similar, to some degree, to ICD-10.

Comparison of monitoring systems for occupational diseases across Europe

As is clear from the descriptions of the various monitoring (or surveillance) systems for occupational diseases that this chapter has evaluated, these systems vary greatly in how they operate, the type of information registered, how biological agents and the related diseases are incorporated into them, and the way in which the output is made available. Table 2 presents an overview of the key parameters that define the occupational disease monitoring systems that this project has evaluated. A general observation, also noted on the basis of the questionnaire responses, is that diseases due to biological agents are generally reported in generic occupational disease recording systems that do not specifically focus on biological agents. However, there are exceptions, as in the literature review a number of focused systems in the healthcare sector were identified, mainly to record blood-borne infections. In addition to the compulsory reporting of occupational diseases in the national systems and a few systems that record work-related diseases such as the zoonoses observatory and the RNV3P system in France, there are systems for compulsory reporting under public health provisions (e.g. for hepatitis or tuberculosis) or networks that collect information on, for example, influenza, such as the networks contributing to the joint European Centre for Disease Prevention and Control (ECDC)/WHO *Flu News Europe* ([41]) initiative.

Number and type of diseases covered by the systems

As described above and shown in Table 3, the types of diseases covered by the systems that were evaluated vary from only prescribed occupational diseases to, in theory, diseases caused by any biological agent. However, only five systems address both work-related diseases and occupational diseases, and only the Danish system for the Registry of Occupational Diseases stipulated 'recognised' occupational diseases. In Germany, however, data are presented for suspected and recognised occupational diseases, and in France and Germany data are presented for those diseases for which workers were compensated. These two countries also provide data on fatalities, which can be linked to infectious diseases as well as other diseases, for example, respiratory diseases. The United Kingdom's LFS and its THOR systems, France's RNV3P and the national notification and registration system of the Netherlands described in this report are not based on compensation. Although in at least some of the countries the output from the systems is also provided in English, in general the most detailed information is available only in the language of the country itself.

With regard to the specified coding system for diagnoses/clinical descriptions used in the monitoring systems as part of the registration process, these were generally comparable to the WHO's ICD-10 codes, although national system-specific lists were also used. A coding system does not necessarily cover all diseases. Furthermore, one monitoring system does not necessarily cover all diseases, and the different systems all cover different ones. Where there are several systems in a country, it may be difficult to know what is actually covered in each system and overall. There may also be the possibility that two systems cover the same disease differently. However, all the coding systems used within the different monitoring systems contain at least some occupational diseases related to biological agents, but the exact number varies and can be very limited; the types of diseases recorded and their coding also vary. In addition, information and guidance provided to those who register occupational diseases and those who assess them for recognition or compensation is not necessarily communicated by the public data available on occupational diseases, in which in some cases diseases are grouped or lumped together in very general categories. Therefore, obtaining an overview of the number of reported diseases due to biological agents on the basis of the outputs from the different systems evaluated and the harmonised national lists is difficult; as a result, it is important to analyse the data with the guidance mentioned above in mind and using the information that is included in such guidance on the causal agents. For the time being, it is very difficult to compare the data from these systems, given what is

([41]) The joint ECDC-WHO Regional Office for Europe *Flu News Europe* bulletin describes and comments on influenza activity in the 50 WHO Member States using routine influenza surveillance systems in the WHO European region. Quantitative and qualitative epidemiological and virological data are reported to the European Surveillance System (TESSy) hosted by the ECDC, after which they are analysed and presented in the bulletin. The majority of countries provide influenza surveillance data to TESSy from more than one surveillance system.

publicly available, and it is impossible to rank the different diseases according to their prevalence, to identify, for instance, the most frequently occurring or recognised occupational diseases across Europe.

What emerges from the analysis, however, is that both infectious diseases and other diseases, such as respiratory and allergic diseases related to exposure to biological agents, were covered by the systems, although the second group was not related to specific biological agents or even exposures. This is in line with what was described in Section 3.2 on allergenic and toxic agents: these diseases are multifactorial, and biological agents, including specific ones, can be identified as one of the causes, but it is difficult to link the effect to one cause or one agent. Diseases registered under respiratory and allergic diseases also represent a high proportion of the diseases linked to biological agents. It may very well be the case that the guidance documents for the different countries and diseases provide more detail. However, particularly for these diseases, it is difficult to link them to a specific biological agent, and this is congruent with the fact that workers affected by these diseases are normally exposed to a mixture of biological agents (for example biological agents in organic dust) and a mixture of biological and chemical agents. This may challenge the definition principle of recognised occupational diseases, which postulates the need for an occupational disease to be primarily caused by a specific agent that can be clearly identified. Nevertheless, some of the systems described in this review do allegedly include diseases aggravated by certain exposures, for instance exposure to biological agents.

What also emerges from the analysis is that zoonoses are recorded to varying degrees, although their importance is recognised in the literature search and by the experts who contributed to this review. Although zoonoses are differentiated in the compensation system (IIDB) in the United Kingdom and are also included in the French sentinel system, this is not the case in the official statistics of occupational diseases in Germany, for example, where they are presented under one category, or at least such information cannot be retrieved from the available statistical sources (SUGA report); zoonoses represented about one quarter of the notified occupational diseases in the latest statistics from 2018.

Coding of causes of diseases as part of the registration process

With regard to detailed information on the causes of registered diseases, the French RNV3P monitoring system is the only one that actually provides information on (assumed) causes of registered diseases on an agent-specific level, actually exposure information, as a result of the French thesaurus TOE, which is used during the registration process. For other monitoring systems, this is not the case systematically. Therefore, it is often difficult to make a distinction between specific biological agents, or even groups of biological agents, when extracting data from a particular system. However, some information on exposures may be recorded, for example in the free-text parts of the recording systems, and may provide information on exposures, and the information about sectors and occupations may indirectly do so too.

Coding of occupations and sectors as part of the registration process

With regard to the coding of jobs/occupations, ISCO-08 was mentioned several times, but, regarding the classification of industries/sectors, there seems to be little overlap in the classification systems applied among industries/sectors. In terms of the coding of the sector in which a particular case is observed, there is no overlap at all with regard to the coding system used across countries. Furthermore, although information about the occupation and/or sector in question is generally considered to be available in the respective databases into which the registered cases are entered, in the output from these systems — which is either presented in the form of, for instance, an annual report or extracted from (the publicly available part of) the databases, this information is generally not specified according to the sectors and/or occupations for which these cases were registered. The number of cases of a specific disease broken down by sector or occupation cannot normally be extracted from these sources, but this is information that is important; for example, it can be used to target prevention to the most affected sectors.

Data extracted from the selected monitoring

Table 3 provides an overview of the data that was extracted from the selected monitoring systems that the questionnaire respondents described above. It should be noted that, in most cases, these data represent the data that are publicly available. There is a limited number of registered occupational diseases due to exposure to biological agents compared with the total number of registered diseases.

In general, the percentage of registered occupational diseases due to exposure to biological agents compared with the total number of registered diseases seems to be relatively low. Registered diseases often comprise infectious diseases and hypersensitivity pneumonitis (e.g. allergic alveolitis, farmer's lung), of which the latter is related to, for instance, exposure to organic dust. Registered diseases are most frequently notified from the agriculture and healthcare sectors.

More detailed extractions of data are included in the report summarising the literature review (EU-OSHA, 2019a).

Table 3: General overview of outputs from selected monitoring systems for occupational diseases in terms of diseases due to exposure to biological agents

Country	Summary of available outputs from evaluated monitoring system
Netherlands	Occupational diseases due to exposure to biological agents account for a relatively small percentage of all reported occupational diseases, but their number is steadily increasing over time (as is the case for occupational diseases in general, probably at least partly due to a higher frequency of reporting). Occupational diseases due to bacteria and parasites are most frequently reported and are considered the major cause of occupational zoonoses, infectious diseases and hypersensitivity pneumonitis, whereas, in half or fewer than half of the other diseases reported, biological agents are indicated as the cause of the disease (e.g. occupational asthma, asthma aggravated by work and contact dermatitis). Within the category of occupational diseases due to biological agents, the focus is on occupational infectious diseases. In 2014, 115 occupational infectious diseases were reported (37 % increase from 2013, and a further increase was observed in 2015), with the highest number of reports in curative heath care, aviation/air transport and the construction industry. Skin conditions were reported most frequently, of which almost half were caused by a fungus infection, followed by airway symptoms and Lyme disease. Occupational diseases in the lungs and airways have shown a steady increase over the years. For around 30 % of these reported cases, biological agents were indicated as the cause of the condition, with plants/vegetable-based products and bacteria most frequently reported as the causes. The highest number of registered occupational diseases related to exposure to biological agents were observed among 'caregivers' (mainly cases of contact dermatitis, intestinal infection and other infectious diseases), but the proportions of registered occupational diseases due to biological agents is highest among non-commissioned officers (army), trained farmers, trained foresters, fishermen and hunters, farmers, cattle breeders, and workers in food processing, indicating that this type of occupational disease seems to occur relatively often in agriculture.
United Kingdom	Dangerous occurrence of biological agents registered under RIDDOR account for 5-6 % of the total. The number of cases of occupational disease/work-related disease caused by biological agents reported under RIDDOR for the period 2014-2016 accounts for around 6 % of the total. The number of cases of occupational dermatitis caused by biological agents (as reported under EPIDERM) is relatively low (and these biological agents are not further specified). However, a large proportion of the 'organic agents' that are specified in relation to occupational asthma (in SWORD) are considered biological agents. In the IIDB system, steady numbers of cases of allergic alveolitis (5-10, linked to exposure to biological agents) and tuberculosis (5) are reported every year. Likewise, 10 cases of Lyme disease and 10 of anaphylaxis due to natural rubber latex products used

Country	Summary of available outputs from evaluated monitoring system
	in the healthcare sector were reported in 2009-2018 ([42]). A considerable number of cases of occupational asthma, rhinitis and dermatitis are also reported, but only a small proportion of these cases is assumed to be caused by biological agents. At least some of the occupational asthma cases (mainly among bakery workers because of exposure to flour dust), COPD (caused by exposure to grain dust), allergic alveolitis, rhinitis and byssinosis, and work-related skin disease (caused by exposure to allergens) are the result of exposure to biological agents. In general, a reduction in the number of cases has been observed over the years (a downwards trend).
Germany	Over the period 2016-2018, of the total number of notifications of suspected cases of occupational diseases, 3-4 % were infectious diseases, around 4-5 % were respiratory disorders and obstructive airway diseases (of which 9-10 % were due to exposure to organic dust), and 38-39 % were occupational skin diseases (BMAS/BAuA, 2020). Notifications have increased recently, but confirmed cases do not show a proportional increase (although these too show a slight increase in recent years). The healthcare sector is a major contributor to the reports of cases of occupational infections, and one of the items in the official statistics is directly linked to the healthcare sector (No. 4301 — infectious diseases — if the insured person was particularly exposed while working in the health service, in the welfare sector or in a laboratory, or through another activity with a similar risk of infection). Among the 3,141 infectious diseases notified in 2018, about 60 % (1,971) were linked to the abovementioned No. 3401 (healthcare sector and laboratories), 857 were zoonoses, and 313 were tropical diseases, including typhoid. Slightly more than half (54 %) of the notified infectious diseases (1,720) were recognised diseases, a much higher proportion than overall (82,622 notified diseases vs 21,794 recognised diseases in 2018, representing about a quarter — 26.4 %).
France	From 2001 to 2015, exposure to biological agents accounted for a relatively small percentage of all reported work-related diseases (2 %) in the RNV3P system. During this period, numbers of reported exposures to biological agents seem to have remained stable, apart from those in the categories of animal and plant material (which seem to be increasing and represent > 70 % of total exposures due to biological agents). Work-related diseases due to exposure to one or more biological agents occurred in seven industry sectors (6-13 % of the total): food industries; health and social care; farming; hunting and ancillary services; retail trade and repair of domestic articles and household goods; construction; hotels and restaurants; and public administration. Reported work-related infectious diseases and diseases caused by parasites over the period 2001-2015 were mainly cases of tuberculosis, followed by mycoses and viral hepatitis. In addition, non-infectious diseases such as hypersensitivity pneumonitis due to exposure to organic dust (e.g. allergic alveolitis, farmers' lung, mushroom worker's lung) were reported. Farmer's lung accounts for one third of all the hypersensitivity pneumonitis cases reported. A further subdivision of the cases of hypersensitivity pneumonitis shows that nearly half of all biological agents belong to the 'fungi, mould' category, followed by 'vertebrates', and the main industry sectors concerned are farming, hunting and ancillary services, and food industries. In the CNAM-TS statistics, the proportion of recognised diseases related to biological agents is low compared with the total number of recognised diseases. Those most prominently represented are tuberculosis and other mycobacterial infections, infections related to infectious agents encountered in hospitals and during care at home, rhinitis and asthma. The latest year for which statistics were available is 2018. Figures were higher for rickettsioses and Q fever in 2016 (CNAM/DRP, 2020). There were 113

([42]) IIDB statistics are available from the HSE website at https://www.hse.gov.uk/statistics/tables/iidb03.xlsx.

Country	Summary of available outputs from evaluated monitoring system
	infectious diseases (about 2 % of the total) reported in 2018 — most of which were linked to tuberculosis and nosocomial infections — compared with a total of 49,538 diseases.
Denmark	In recent years, the numbers of notifications of occupational diseases related to biological agents have been relatively stable (1-2 %). In general, the percentage of registered diseases caused by biological agents per sector has been relatively low and constant over the years (on average, 1.2-2 %). However, in some sectors such as agriculture, forestry and fishing, the food and beverage industry, restaurants and bars, and hotels and camping (2-6 %), this percentage is relatively high, indicating that biological agents are a risk factor that needs attention.
Finland	The numbers of cases of reported occupational diseases have either remained stable or declined in recent years, with the number of suspected diseases being much larger than that of those that are finally recognised. The industry with the most cases is agriculture. The proportions of cases of allergic and skin diseases are increasing because of a decrease in other diseases. With respect to occupational diseases due to exposure to biological agents, allergic diseases are reported most frequently (mainly allergic asthma and allergic rhinitis, and to a lesser degree also allergic alveolitis and laryngitis). Reported skin diseases do not seem to be closely related to biological hazards.

Monitoring systems for emerging occupational health risks

The purpose of sentinel and alert systems varied widely, according to the responses given by the questionnaire respondents for task 1. The respondents indicated that these systems were mostly used as an input for prevention programmes, policy-making and research. Although some of the mentioned sentinel or alert systems concerned a specific agent or disease, most of the systems focused on biological agents in general.

Some of the monitoring systems for emerging risks that were mentioned by the respondents and/or that were evaluated in more detail cover the identification of new and/or emerging occupational diseases (or risks), and often involve a process of evaluation by a group of experts. The detection of new and/or emerging risks requires a different strategy/instruments from the ones used for the detection of existing (mostly prescribed) occupational diseases.

An example of a separate monitoring system for emerging occupational health risks is SIGNAAL in the Netherlands and Belgium, which is a notification system for new and/or emerging risks. In this system, physicians can submit a case to an online database when they suspect a new/emerging risk to health. Of the 17 cases that were reported from July 2013 (when the system was established) to 26 April 2017, at least 4 were related to biological agents:

- endotoxin fever after spray-cleaning a contaminated waste pipe (not new but not yet described for this work situation);
- repeated airway infections when frequently passing through time zones when flying (not completely new but not yet reported);
- immune-mediated pathology in a sewage treatment station after accidental bacterial excess mortality (not new but relatively unknown);
- extrinsic allergic alveolitis among workers at a metalworking company (metalworking fluids) (not new but not previously reported in the Netherlands).

Another example is the Emergence Working Group, which operates as part of the French RNV3P monitoring system. The mission of this group is to establish a platform for sharing information, to assess the early detection of potentially emerging diseases and to set up a process for reporting any occurrence of an emerging disease. The signals discussed by the working group experts (occupational physicians, university professors, representatives of national partners) are clinical case reports by occupational disease clinics, statistical signals of emergence (based on data mining in the national RNV3P database)

and specific search results (in the literature, case studies reported by NIOSH, information from the European Modernet Network after alerts from other sources or organisations. So far, 60 reports have been or are being assessed by the experts in this working group, of which only 3 reports were related to exposure to biological agents, namely:

- inhaled corticosteroid and lung infection with atypical mycobacteria (*Mycobacterium fortuitum*);
- asthma and exposure to *Chrysonilia sitophila* in a coffee machine service agent;
- pneumococcal vaccine in metallurgical workers.

The cases mentioned above are illustrative of the risks occurring in workplaces and span the whole range of risks identified in this review — whether through the literature or through the assessment carried out by the experts — including infectious diseases, respiratory diseases and immune-mediated diseases, as well as the occupations whose risks have been described in this report.

For the detection of emerging risks, different instruments from those used for monitoring known occupational diseases may be needed, as mentioned above. The choice of instrument is determined by the characteristics of the risk, such as the nature and the seriousness of the health effect and the strength of the causal link with the possible cause. A report of the European Commission on occupational diseases (2012) concluded that it is not possible to detect emerging OSH risks using a single method, so several complementary methods are necessary. Instruments that are proposed in this report are the sentinel case approach, epidemiological studies and health surveillance studies. The sentinel case approach refers to analysing and learning from occupational accidents, as is common practice in OSH management. In addition, well-designed epidemiological studies, facilitated by 'record linkage' between health outcomes and occupational data can be very valuable.

There is currently no system in place in Europe that can respond quickly to emerging risks from biological agents; such a system could build on the epidemic alert systems in place in public health systems, and cooperation between both policy areas would be beneficial. In addition, Member States could build alert functions into their national systems that are able to feed directly into the prevention systems for public health and occupational risks.

3.5.3 Monitoring exposure to biological agents

Monitoring systems for occupational exposures

Not all European countries monitor and register occupational exposures on a regular basis. A large proportion of the monitoring systems for occupational exposures mentioned by the experts in the survey performed under task 1 of this review were similar to the occupational disease monitoring systems operated in their countries, and in general the main purpose of each system was the registration of occupational diseases, suggesting that, in quite a few countries, exposure data are mainly gathered when diseases are registered. The respondents further indicated that existing exposure systems are mostly registration systems for exposures, surveillance studies/programmes, exposure assessment and information systems. They also reported that the data gathered in the systems are mostly used for policy-making, prevention programmes and research.

In the stakeholder seminar (task 4), the participants agreed that the current challenges facing all Member States are a lack of exposure data and proper monitoring tools, under-reporting of occupational diseases, and the variety and unclear definition of biological agents. A lack of exposure data in particular was considered to be a major issue and of most concern in eastern Europe. The quality of the exposure data collected also varies greatly. Furthermore, the mapping of exposure to biological agents is an issue because (1) exposure is known to change over time, (2) biological agents are not visible, and (3) there is a lack of staff to perform the measurements. Factors that may facilitate the monitoring of a specific agent or exposure are the identification of a specific (bio)marker or the development of measuring devices from which the results can be read out directly. Yet the use of biomarkers is considered challenging, as no specific biomarkers are available for exposure to biological agents. It was mentioned in the seminar that quantifying exposure is very expensive, and therefore a qualitative approach to exposure should be encouraged as a first step.

The person registering diseases in the monitoring systems may add valuable information on the type of exposures that are related to health effects, which in turn may provide valuable input into the development of an effective prevention programme. The French TOE, which matches exposure to disease, is a good example of this. The aim of TOE is to provide stakeholders with a common reference tool for coding occupational exposures. It does not provide information on exposure levels but does provide an assessment of work-relatedness.

In general, workplace exposures are measured on a structural basis, and this also applies to biological agents. Owing to the large variety of microorganisms present in workplaces, which in most cases require a specialised measurement and/or analytical method, assessment of exposure to individual species is challenging. Of the European countries included in the evaluation (Denmark, Finland, France, Germany the Netherlands and the United Kingdom), only in Finland, France and Germany are occupational exposures monitored and registered on a regular basis. Therefore, only a limited amount of information on exposure to biological agents is available. Only sometimes are biological agents measured on a regular basis in other countries. However, these data are often not publicly available, and the databases do not necessarily contain the exposure levels of biological agents, i.e. only the type of exposure is registered instead of the level of exposure.

In Germany, occupational exposures are monitored through research projects or as part of routine data collection conducted by BAuA, the DGUV or the IFA, other accident insurance institutes, employers' liability insurance associations and universities. BAuA and the DGUV are engaged in research and policy-making.

Measurements of occupational exposure to biological agents are not obligatory and biological agents have no set OELs, although a technical control value is available for the spores of mesophilic moulds in the workplace air of waste-handling facilities. Some accident insurance institutes have, however, established individual data collection strategies for biological agents. Since 2000, data on exposure to biological agents have been stored in the MEGA database, which is maintained and evaluated by the IFA for prevention purposes, for epidemiological assessments, for retrospective exposure assessment, and for the determination of exposure in specific workplaces, including moulds, bacteria and endotoxins. However, the MEGA database is not publicly accessible. Furthermore, no overview of exposure data on biological agents is available from this database.

Publications containing MEGA data are available through the DGUV, and some of them cover biological agents (see, for example, DGUV, 2016b). The Biological Agents Unit of the DGUV analysed the MEGA data for concentrations of moulds and endotoxins in workplaces. An extract from this analysis has been included in Appendix 4, 'Exposure levels for mould fungi and endotoxins in various work areas', of TRBA 400 on risk assessment of biological agents (ABAS/BAuA, 2017). It provides results of the measurements of mould, fungi and endotoxins in several of the sectors mentioned in this review, such as waste management, composting, recycling, agriculture, and textile fibre production and processing, as well as storage areas of, for instance, crops. Other studies mentioned in this report cover microbiological contaminations of cutting fluids and measurements of endotoxins in the textile industry.

In France, the French Research and Safety Institute for the Prevention of Occupational Accidents and Diseases (L'Institut national de recherche et de sécurité pour la prévention des accidents du travail et des maladies professionnelles, INRS) collects the results of air measurements taken in workplaces. This is performed by eight French regional health insurance funds, inter-regional chemical laboratories and the laboratories of the INRS, and the data are recorded in the COLCHIC Occupational Exposure to Chemical Agents Database. The focus of the measurements in COLCHIC seems to be more on chemical substances, and it is not clear if data on exposure to biological agents are also collected. In addition to the COLCHIC database, the occupational exposure database SCOLA results from the French requirement that measurements made during the assessment of compliance with regulatory OEL values should be archived in a national register. The measurements stored in SCOLA are carried out by independent certified laboratories. No information on exposure to biological agents seems to be available in the SCOLA database; however, this is to be expected, as no OELs for biological agents are known to exist in France.

In Finland, FIOH records exposure measurements taken as part of the occupational hygiene services it provides to companies, which are performed to fulfil the legal requirements, based on EU law, for

employers to take preventive action. The biological agents measured mainly involve endotoxins, moulds, bacteria and parasites in workplaces. IgE and IgG ([43]) antibodies in exposed workers in these workplaces are also measured. The data are not publicly available but can be analysed on request. On the basis of this database, FIOH has developed FINJEM, which holds data on exposures to organic dusts and exposures to microbiological agents. This could also be of value to other countries.

The participants in the stakeholder seminar stated that data from monitoring systems should also be made available and harmonised for risk assessment purposes by means of, for example, a job exposure matrix. However, up until now, data has been difficult to compare because of differences in the definitions used for biological agents and the different monitoring systems used in Member States. It was also recommended that the International Organization for Standardization (ISO) should define standards for monitoring biological agents. Harmonisation of the definition and classification of biological agents were also considered a necessity, as mentioned before, as it is important not only for the characterisation of diseases and elucidation of their causes, but also for monitoring exposures.

Thus, in some of the countries that have regular exposure monitoring in place, occupational exposure to biological agents is also measured. These data are mostly not publicly available and, because the data generally available in these databases are not described in detail, there is a lack of information on exposure levels and the occurrence of these exposures in various industries/sectors.

Measurement methods for biological agents

There are a number of challenges to the measurement of biological agents in workplaces, which were described in the literature review (EU-OSHA, 2019a):

- Most biological agents are living microorganisms. A single exposure measurement is only a snapshot of the concentration of biological agents in the air. Thus, to get an accurate picture of the exposure, repeated measurements are needed. In addition, exposure concentration is

([43]) Immunoglobulin G (IgG) is a type of antibody. Representing approximately 75 % of serum antibodies in humans, IgG is the most common type of antibody found in blood circulation.

highly dependent on the season and the place in which it is measured. This complicates generating a representative picture of exposure via the air.

- Available measurement methods often focus on measuring biological agents in the air. Skin exposure to biological agents in the work environment has hardly been studied. However, in many situations oral or dermal exposure (e.g. hand-foot contact, hand-nose contact) is also considered relevant due to surface contamination, although standardised measurement methods do not exist for these exposure routes. The review has identified a number of infections (mainly fungal infections) that should be assessed. Furthermore, contamination of the hands can favour the spread of disease and increase the infection risk of an individual.
- Only a few standardised methods for biological agents are described. However, no methods are available for the measurement of exposure to specific microorganisms in the air. Most methods are labour intensive and can be performed only by specialised laboratories:
    - The 'viable' methods are based on the culturing of the viable organisms isolated from the air and measuring the number of CFU, for which the result is expressed in a plate count (CFU/m³). These methods detect only viable parts of the microorganism but do not help quantify the (non-viable) toxic or allergenic components of biological agents, which can be contained in dead microorganisms or fragments of microorganisms.
    - An alternative is the 'non-viable' methods, which determine microorganisms by (electron) microscopic counting or map exposure to specific agents.
    - Methods that also make use of the genetic information of specific microorganisms are becoming increasingly available. For instance, polymerase chain reaction technologies make it possible to measure small amounts of DNA to enable quicker and more specific detection (Wéry, 2014).
    - In addition, more and more IgE antibodies are available to quantify exposure via enzyme-linked immunosorbent assays, or ELISAs (tests that use antibodies and colour change to identify a substance).
    - It is to be expected that the methods would need to be combined to get a full overview of potential exposures. In a review in 2012, Eduard et al. referred to three different measurement methods for constituents of biological agents: endotoxins and beta(1→3)-glucans, enzymes and mycotoxins.

Some of the countries, such as Germany, have reported on research into measurement methods. Project results are published in scientific papers or as reports in German or English. To further explore the relationship between high bioaerosol concentrations in livestock production facilities and respiratory disorders in exposed workers, the BAuA group on biological agents conducts field sampling and subsequent bioaerosol investigations using microbiological and molecular techniques. Further research fields in relation to occupational exposure to biological agents are waste recycling and paper production.

One focus of the research performed by BAuA, the IFA and other institutes is the quantification of exposure. Since many airborne microorganisms are not readily amenable to cultivation, culture-dependent investigations are complemented with culture-independent microscopic quantification techniques based on DNA staining ([44]).

Another focus is identification: genetic information is obtained from DNA that has been isolated from bioaerosol field samples and prepared for DNA sequencing. Information on bioaerosol composition (i.e. on microbial species occurring in the air of sampled workplaces) is gathered from DNA sequences and interpreted using the available information on occurring microbial species. This method also allows for the identification of novel species and may thus lead to further investigation into their putative contribution to occupational health disorders.

([44]) Staining is an auxiliary technique used in microscopy to enhance contrast in the microscopic image. Stains and dyes are used to highlight structures in biological tissues for greater visibility. In biochemistry, it involves adding a class-specific (DNA, proteins, lipids, carbohydrates) dye to a substrate to qualify or quantify the presence of a specific compound.

Occupational exposure limits for biological agents

During the interviews as well as the focus group sessions, it was repeatedly stated that (standardised) measurement methods and the derivation of OELs are considered necessary for effectively monitoring, controlling and even preventing risks of biological agents in the workplace. Limitations in exposure assessment methodology and a lack of health-based (recommended) OELs for biological agents make it difficult to provide a reference value for prevention. The difficulty in providing a reference value is assumed to hinder the implementation of targeted preventive measures and thus a systematic approach to workplace prevention of these risk factors.

In the countries identified in this review in which exposure measurements are performed, some guidance values are in place, but no OELs have been set to date.

In principle, it is possible to derive OELs for biological agents that primarily cause toxic effects in the same way as is done for other non-carcinogenic substances (using methods such as the no-observed-adverse-effect-level method, the benchmark dose method or another similar statistical model for human data). However, the lack of good (quantitative) data on exposure and associated toxic effects (the exposure-effect relationship) hampers the actual derivation of such OELs in practice. In addition, as the variety of biological agents that give rise to, for instance, infectious diseases is wide, determining one overall effective OEL to apply to all such biological agents is not considered possible. As quantitative information on exposure, pathogenicity, the disease and the relationship between them is needed to determine health-based recommended OELs for individual agents, it is not very likely that it will be possible in the short term to determine many OELs for biological agents that lead to infectious diseases. In the meantime, a precautionary approach to these agents should be taken, in which exposure is avoided or kept as low as reasonably or feasibly possible. It should be noted that, for viable agents, which may replicate upon infection, the minimum infection leading to adversity may very much depend on person-to-person variation (e.g. in the case of immunocompromised individuals). Moreover, for some agents, the minimum infection grade leading to a disease may be very low, depending on the pathogenicity of the organism.

Existing reference values for biological agents

As mentioned above, some examples do exist of relevant OELs that provide benchmarks, even if they do not address a specific biological agent, or other reference values. Reference values for moulds, flour dust, organic dust and endotoxins have been referred to in Sections 3.2.1, 3.2.2 and 3.2.4, where exposures to allergenic and toxic substances linked to biological agents in specific sectors are described. In the Netherlands, a health-based recommended OEL was derived for endotoxin exposure and inhalable grain dust. In the United States and the United Kingdom, limit values were set for total grain dust (wheat, oats, barley) and for grain dust, respectively. In Scandinavia, the Nordic Expert Group examined the effects on health of moulds capable of producing toxic effects. The level of moulds in the air at which non-sensitised workers start to experience effects was calculated to be about 10^5 spores/m^3 air, but no recommendations for an OEL were made. The ACGIH states that concentrations of moulds in indoor air should generally be lower than outdoor air concentrations. In addition, no microorganism species should be found indoors that is not usually present outdoors (during the corresponding season).

Although in the Netherlands no OELs have been set for living microorganisms, global occupational hygiene rules in the assessment of measurement data are often used in practice, based on the amount of CFU as a measure of the concentration of bacteria, fungi and yeasts in the air. For the total number of bacteria and fungi, a maximum of 10,000 CFU/m^3 is used; for the individual categories of bacteria, yeasts and fungi, a maximum of 500 CFU/m^3 is used; and for Gram-negative bacteria, a maximum of 1,000 CFU/m^3 is used.

Limit values for allergens

Allergens are characterised by increased sensitivity of the immune system (sensitisation), induced by earlier exposure. Sensitisation may be asymptomatic; several instances of exposure may be required before evidence of allergic sensitisation is seen; and in a sensitised person renewed exposure may ultimately lead to allergic respiratory symptoms. As it is suggested that a threshold level exists for inhaled allergens, OELs could be calculated in the same way as they are for other non-carcinogenic substances. However, the relevant threshold levels for allergens may in general be too low to be

measured using the available techniques. If deriving an OEL is not possible, reference values (exposure levels that correspond to predefined accepted levels of risk of allergic sensitisation) could serve as an alternative, which in turn could be used as a basis for deriving OELs. In this case, the concept of an acceptable risk would need to be applied instead of deriving an OEL below which no health effects are expected to occur.

However, sufficient toxicity and effectiveness studies are currently available for only a small number of allergens, and therefore only a limited number of limit or reference values for allergens is known to be available. In the Netherlands, reference values for exposure to wheat and other cereal flour dusts, fungal alpha-amylase and dust from processed de-hulled soybean flour are derived, related to a sensitisation risk of 1 % compared with the background risk of the general population. In the case of flour dust, several countries, such as Sweden, the United Kingdom and the United States, have set limit values. The ACGIH in the United States has also established a TLV for subtilisin, an enzyme of bacterial origin that is used as a detergent, for example, and is produced with the aid of GMOs. The effects of industrial enzymes generated by microorganisms are described further in Section 3.2.2 of this report.

A technical control value that supports a review of the effectiveness of technical measures in certain branches of waste management is included in the German TRBA/TRGS 406 (ABAS/BAuA, 2008).

3.5.4 Classification of biological agents

An important aspect of monitoring systems is how biological agents are categorised and classified. Both France and Germany have classification systems in use that can serve as practical examples of harmonisation. The aforementioned French TOE includes a dedicated classification system, divided into two dimensions, namely (1) substances and agents and (2) context of use and industrial process. As mentioned before, about 3,000 out of the more than 8,000 labels are related to biological agents, which are divided into the following categories: microorganisms (bacteria, viruses, fungi and parasites), animal (invertebrates and vertebrates) and plant material.

In Germany, the system of classification of biological agents into risk groups is organised by ABAS, following a procedure and criteria outlined in TRBA 450 (ABAS/BAuA, 2016a), and is based on and expands on the regulations of Directive 2000/54/EC. Classified biological agents are listed in individual TRBAs for bacteria (TRBA 466), fungi (TRBA 460), viruses (TRBA 462) and parasites (TRBA 464) (ABAS/BAuA, 2012, 2013b, 2015, 2016b). In addition to the biological agents listed in Annex III to Directive 2000/54/EC (classified in Risk Groups 2-4), the German classification system also includes biological agents classified in Risk Group 1, which do not have the potential for infection according to current knowledge. Particular attention is paid to both the infection potential, which determines the classification, and the sensitising and toxic potential of the biological agents. If biological agents have hazardous properties independent of their infection potential, this is notified through the use of additional labels. ABAS is also cooperating with AGS on, for example, sensitisers. TRBA/TRGS 406 'Substances causing airway sensitisation' sets out prevention measures for sensitisers originating from moulds (e.g. *Aspergillus spp.*), bacteria (e.g. *Thermoactinomyces vulgaris*), mites, components of bacteria, materials from plants such as grain and fodder, animals, for example animal hair, and chemical substances such as disinfectants (ABAS/BAuA, 2008). Examples of sectors such as agriculture and forestry, animal facilities, waste management are also included, and it includes a TVC that supports a review of the effectiveness of technical measures in certain branches of waste management.

The German GESTIS Biological Agents Database, part of the hazardous substance information system of the DGUV and maintained by IFA, is also a good example of how information can be organised and made available. This database is publicly available and contains information on, for example, safe activities with biological agents in the workplace and important properties of the various biological agents, such as their occurrence and pathogenic properties. It comprises data on about 15,000 biological agents and uses the classification system described above. Switzerland also has a classification system for biological agents. A more detailed description of the GESTIS Biological Agents database is included in the literature review and in a dedicated article published on EU-OSHA's OSHwiki (EU-OSHA, 2017).

4 Conclusions, discussion and recommendations

In 2015, EU-OSHA commissioned this review to:

- assess existing information on:
  - health problems related to exposure to biological agents (paying particular attention to vulnerable workers and covering infectious agents, airborne aerosols and allergens),
  - work-related health effects and diseases linked to exposure to biological agents at work,
  - biological agents (including those that are less known, and emerging exposures to biological agents in new professions and new industrial activities),
  - recognised and compensated occupational diseases linked to exposure to biological agents in Europe,
  - monitoring systems that record work-related diseases linked to biological agents and/or exposure to biological agents (including their limitations), and
  - major reviews related to the implementation of Directive 2000/54/EC on the protection of workers from risks related to occupational exposure to biological agents in the EU;
- identify databases and datasets that provide systematic information on biological agents and risks to workers;
- identify gaps in data and knowledge.

It also aimed to collect the views of experts and workplace practitioners on current policies and practices to prevent the risks related to occupational exposure to biological agents, and support more targeted and structured prevention.

The review should complement and update existing EU-OSHA research on, for example, emerging biological risks, pandemics, antibiotic-resistant microorganisms, health and safety in laboratories, green jobs and the management of *Legionella* at work. It should also:

- provide up-to-date information regarding health problems and diseases linked to biological agents and raise awareness among beneficiaries;
- provide information on structured approaches to their recognition and prevention that may support beneficiaries in designing policies and prevention measures, including practical advice for the enterprise level;
- contribute to the sharing of information on these diseases to support the implementation of EU Directive 2000/54/EC, especially as regards workers' unintended exposure and biological risks in emerging sectors and occupations.

This report set out to provide a consolidated overview of the findings of all parts of this review and proposals for policy options, linking the findings of tasks 1 to 4. This section contains a summary of and conclusions based on the results of the scientific literature review, the questionnaire survey and the evaluation of selected monitoring systems, as well as the expert interviews and the focus groups with workplace practitioners. The results from the discussion of the findings at a workshop with participants from most EU Member States, nominated by EU-OSHA's national focal points, are also incorporated. This section is organised around several themes that are considered important; it also identifies data gaps and includes recommendations for the future. When there were different conclusions from different tasks or when different views were expressed, this is highlighted in the review.

EU-OSHA research on emerging biological risks and national reviews (e.g. from Germany and Australia) have highlighted the lack of knowledge and awareness of exposure to biological agents and the related health problems.

The experts who participated in this review often considered it difficult to characterise work-related health effects caused by biological agents because, for example, the biological agents that workers are exposed to — the cause of the disease — are not always intentionally introduced in a work process/work environment (i.e. they are accidental or unintended exposures). One of the objectives of this review was to identify such unintended exposures and discuss with experts and workplace practitioners how they can be prevented, in order to support more systematic prevention. Moreover, some of the health effects

related to exposure to biological agents are rather unspecific, meaning that they can be caused by a wide range of factors, which makes it even more difficult to monitor these diseases and identify whom they target.

Workplace risk assessment may also be challenged by the fact that workers in these sectors may be exposed to many biological agents, and many of these may occur naturally. Whenever people are in contact at work with the following, they may be exposed to biological agents (EU-OSHA, 2003):

- natural or organic materials, such as soil, clay and plant materials (hay, straw, cotton, etc.);
- substances of animal origin (wool, hair, etc.);
- food;
- organic dust (e.g. flour, paper dust, animal dander);
- waste and wastewater;
- blood and other body fluids.

This already gives an idea of the many occupations that might be affected by mostly unknown microorganisms in their work environment.

It should be kept in mind, however, that the Biological Agents Directive states that the obligations of employers still apply, even if the results of the workplace risk assessment show that an activity does not involve a deliberate intention to work with or use a biological agent but may result in workers being exposed to a biological agent, as in the activities listed in Annex I to the directive:

- work in food production plants;
- work in agriculture;
- work activities in which there is contact with animals and/or products of animal origin;
- work in health care, including isolation and post-mortem units;
- work in clinical, veterinary and diagnostic laboratories, excluding diagnostic microbiological laboratories;
- work in refuse disposal plants;
- work in sewage purification installations.

The directive also clarifies that, in relation to biological agents, there may be other work activities that involve unintended exposure that are not included in this annex, which should be considered.

4.1 Results

Based on reported exposures and health effects in the scientific literature search as well as on the input of the experts and workplace practitioners during the interviews and the focus groups, some more frequently addressed industrial sectors and occupations were identified in which exposures to biological agents are of concern: animal-related occupations; waste and wastewater treatment; the healthcare sector; arable farming; and occupations that involve travelling or contact with travellers. These sectors mostly coincide with the ones identified in the annex to the directive. The associations between occupation and the occurrence of diseases resulting from biological agents are (reasonably) clear for some of these occupations. Information on the number of workers affected and the dose-response relationship is, however, not available. It is therefore nearly impossible to gain an appreciation of those risks that are particularly prevalent or serious or rank them in order of importance or relevance, either by estimating the number of workers that may be affected or the seriousness of the health effects, or by ranking the biological agents, risks, health effects or sectors in order of importance. Unfortunately, the available outputs from most of the monitoring systems for diseases did not make a detailed review of the data with regard to industry, occupation, gender or age possible, although some findings point to food production, waste management, health care and construction, and to the risks posed by tropical diseases imported by travellers and workers working abroad. Public availability of the data seems to be a limiting factor; however, farmer's lung, diseases in food production, hepatitis, travel-related diseases and baker's asthma are relevant issues, as are smaller outbreaks of, for instance, zoonoses, which were also referred to in the questionnaire answers regarding case studies of diseases, as well as in the focus groups and expert interviews.

Much of the information on the potential exposure of workers to biological agents has already been reported in detail in the literature review, with extensive tables providing an overview of agents and related diseases, and an extensive summary is available in EU-OSHA's first report for the project (EU-OSHA, 2019a). However, a number of issues identified in that report were also picked up by the OSH experts and workplace practitioners and are referred to below.

A general lack of awareness

In general, an overall lack of awareness of the risks posed by biological agents can be observed in all sectors except in health care and laboratories, although it seems that, even in these sectors, not all stakeholders have the same level of knowledge, and some vulnerable groups have also been identified, such as young people in training and cleaners. Of all the sectors considered in this review, the healthcare sector is the one in which most information regarding work-related diseases due to exposure to biological agents is available. Some of the experts thought that the healthcare sector was not as problematic as the other sectors of concern because of its proper regulation and relatively high awareness of biological risks and because workers respect the rules.

Although a general lack of awareness was reported by the OSH experts at enterprise level, the following important risks were identified in the literature review and also mentioned by the experts:

- The health risk most frequently reported in health care is accidents with sharp objects (mostly needlestick injuries), and the experts claimed that many measures could further reduce this risk, such as the introduction of safe needle systems, vaccination and the use of protective clothing. Risks from multi-resistant strains of bacteria or children's diseases were also mentioned as significant. Furthermore, policy measures for the prevention of epidemics, including serious infections, such as infections with the Ebola virus, were reported.
- In the waste treatment sector, infections such as HIV infection and hepatitis B infection caused by sharps injuries and adverse respiratory effects due to exposure to bioaerosols or organic dust were mentioned as the most significant risk. Many of the experts stressed the need to vaccinate workers and introduce hygienic measures.
- In arable farming, workers are considered to be exposed to a diverse range of biological agents owing to their work with crops, which can lead to various diseases. Tick-borne

diseases and lung disease (allergy) are most abundant in this sector, and workers are frequently exposed to organic dust.

- Workers in animal-related professions are known to be at risk of infection from a wide range of bacterial, viral, fungal or vector-related microorganisms. Multi-resistance to antibiotics (because of the use of antibiotics in animal breeding) and exposure to organic dust were also mentioned as significant risks, mainly caused by the way in which animals are reared intensively. Respiratory health effects among animal farmers were frequently mentioned and reported.

Emerging risks

In the literature review and in the qualitative research with experts for this review, new and emerging risks were also addressed, although validation of the information that was retrieved is not straightforward. Information on the prevalence or incidence of exposure to biological agents and the associated diseases is scarce. Therefore, it is difficult to assess if diseases caused by biological agents occur more frequently and if a possible increase in frequency is due to changes in exposure. However, some issues seem to be linked to new developments — such as climate change and environmental legislation leading to changing patterns in waste management — newly occurring microorganisms that have spread to other regions, or better knowledge or awareness of some issues, and these developments are described here.

Based on the scientific literature review and the expert interviews, (re-)emerging risks due to biological agents are considered of primary concern in the following sectors and occupations: occupations that involve travelling and contact with travellers, health care, agriculture (animal breeding, food production and forestry) and waste management/recycling/sewage systems. In addition to the issues already identified in the literature review, the OSH experts mentioned that attention should be paid to multi-resistant bacteria and epidemics of zoonoses, especially in emissions and regarding their transmission through the air. Potential re-emerging risks in the healthcare sector and agricultural sector such as Q fever, tuberculosis and influenza were also mentioned. Climate change is associated with a wider spread of some diseases and their vectors (e.g. mosquitoes and ticks). A wide range of tick-borne diseases is putting workers in many professions at risk. Climate change could also cause the migration of populations, bringing new diseases to new areas. The risks posed by globalisation and changes in travelling patterns were other issues raised by the experts. Globalisation has resulted in fast travel opportunities and the import and export of products, which means biological agents could spread more easily and faster than before. In addition, some experts expressed their worries about the possibility of mutations of viruses affecting animals becoming a danger to humans, especially when infection can occur through inhalation. It would be advisable to consider these major global issues when developing new protective measures.

Stakeholders had also mentioned a few issues in addition to those identified in the literature review, such as the resurgence of tuberculosis linked to, inter alia, the migration of people from outside the EU;

the wider spread of vector-borne diseases and leptospirosis linked to climate change; and the issue of new viruses. The Zika virus has recently caused concern, yet it was not prominent in the literature search. In addition to these issues, experts and stakeholders highlighted the resurgence of common childhood diseases, the unpredictability of allergic reactions and the importance of addressing antibiotic resistance. Finally, GMOs and tetanus were two issues that were not identified in the literature survey and were not addressed by the experts and workplace practitioners.

For animal-related occupations, especially animal farming, the increasing industrialisation of activities was recognised as an issue because of the increase in the size of industrialised farms and the numbers of animals, thereby facilitating the spread of diseases. Intensive breeding and technological changes in agriculture are also putting workers at risk of being exposed to organic dust, a complex mixture of dust and microorganisms. Workers in other professions, such as waste handlers and compost workers, are also exposed to organic dust. The risk of exposure to surgical smoke because of the introduction of new surgical techniques, for example, is another risk identified in the literature review, but it is not addressed by the experts consulted in this review.

The increased resistance of microorganisms to antibiotics was another risk mentioned in the literature and tackled in several Member States; this development puts care professionals as well as workers in the agricultural sector at risk because of the widespread use of antibiotics and intensive breeding.

During the focus group sessions, the intermediaries shared their views on both current and emerging risks in three of the five sectors identified above, namely animal-related occupations, the waste treatment sector and the healthcare sector. Many of the risks were seen as both current and emerging, and therefore a differentiation was hard to make. With regard to controlling both current and emerging risks due to biological agents, the OSH experts talked about several issues that are applicable to a range of sectors, and the prevention measures proposed are referred to here and in Sections 4.1.1 and 4.1.2. The experts recommended additional measures against a variety of risks, and these are related to organisational measures as well as technical protection measures and automation. A few examples are referred to in Table 4.

A wide range of occupations at risk from infectious diseases transmitted by animals or vector-transmitted diseases

This review observed an increased risk of contracting bacteria-, virus-, fungi- or vector-related infections among all the animal-related occupations addressed, and this impression of the scientific literature was confirmed by the OSH experts. Among abattoir and slaughterhouse workers, bird-related zoonoses, bacteria-related diseases and tick-borne diseases may occur more frequently. Veterinarians may contract an infection from direct animal contact or bites by vectors (e.g. ticks, lice). Exposure to multi-resistant microorganisms such as MRSA in pig farms was also often reported as a concern. It was reported that the high number of animals reared intensively may lead to bacterial resistance to antibiotics.

Other occupations that were identified as being at risk were laboratory workers who are in contact with animals, and zoo workers. Specific risks for these workers were identified and are referred to in detail in the literature review (EU-OSHA, 2019a) and in Section 3.1.1 of this report, as well as information about efforts to prevent them. In France, for example, a lot of effort was put into the prevention of the transmission of BSE and zoonoses. Since 2008, an observatory — Zoonoses Surveillance in Agriculture, — has allowed doctors working for sectoral social insurance organisations (e.g. CC-MSA) to report cases of zoonosis (using standardised reports). These reports provide information that can be used to confirm the diagnosis and the relationship between work and the transmission chain. Each report is validated and is added to a database (which is not publicly available). The statistics from this database are not representative of all French agricultural workers, as they depend on voluntary input from doctors, but a goal of the observatory is to create a qualitative and analytical database on exposure to biological agents. France, like other countries, also has policies to improve the prevention of rare diseases arising from biological agents among humans and animals (e.g. Q fever). These include surveys on animal and human health, monitoring of people who are in contact with biological agents and the provision of prevention management advice to companies on the basis of worker complaints. The measures are tailored to the company, which results in greater willingness of workers to cooperate.

The SARS epidemics, as well as the recent COVID-19 pandemic and other serious zoonoses such as BSE, have shown that urgent measures are needed to protect workers from the impact of a transmission of infectious diseases from animals to humans. What these epidemics have also shown is that a broad range of occupations could be affected by such diseases, although at the outset this may not have been recognised. One issue mentioned by the experts in this context is pandemic and epidemic preparedness, and another is the monitoring of these serious diseases. The respondents to the questionnaires in task 1 mentioned several cases of smaller outbreaks, for instance Q fever, at the local level. Given the wide range of agents in question and the variety of sectors affected, raising awareness of these threats is urgently needed among all actors and the importance of the topic needs to be brought to the attention of policy-makers. Emergency plans for such incidences should be set up in businesses, but most of the time they are missing, whether it concerns an outbreak of a zoonosis in the farming sector or in the healthcare sector. This obligation, which is also a requirement for employers according to the Biological Agents Directive, should be made more operational and be brought to the attention of sectoral organisations, together with the documentation requirements that come with it (recording cases of exposed workers and informing them).

The information collected by compulsory reporting obligations could be valuable to identify early signs of the spread of a serious disease and could be used to issue alerts to the actors in occupational safety and health. Cooperation with stakeholders across policy areas (food safety and animal health, public health) would be warranted, and this seems to be the aim of some of the monitoring systems for zoonoses that were referred to in this report and the stakeholder survey, such as those established in France. Epidemics could be predicted by regional observation groups, with field stakeholders (sentinel practitioners, emergency services, etc.) performing surveillance and reporting to central authorities.

Greening of the economy may have impacts on exposure to biological agents

Waste treatment and composting are associated with exposure to a variety of microorganisms and structures originating from these microorganisms, including specific allergens. According to the intermediaries, the sector is characterised by exposure to a combination of risks (chemical, biological, physical), including a combination of biological agents and biomass-related allergens. Waste treatment encompasses a number of occupations that are included in the term ‘green jobs’. Regarding the occupations addressed in their discussions, the experts agreed with the finding of the literature review that the expected increase in green jobs in the future may result in an increased prevalence of sensitisation to biomass-related allergens, increased disease rates and even new work-related diseases. The topic of allergens and organic dust exposure prevention proved a challenging one, both because the composition of dust may vary considerably and because the exposure is difficult to describe qualitatively, in terms of the agents, and quantitatively, in terms of exposure. There are hardly any exposure limits available (a few are referred to in Section 3.2) and measurement methods are very limited, for both identification and quantification of biological agents. The experts called for more efforts to develop methodologies for the measurement and monitoring of these exposures and for prevention.

Prevention of allergies should be a priority

Biological agents that are regarded as occupational hazards can be subdivided into two main groups, namely:

1. microorganisms that cause infectious diseases, for example zoonoses, which are contagious diseases that are transferred from animals to humans;
2. allergenic and/or toxic agents that form bioaerosols (e.g. bacteria, endotoxin, fungi) and cause diseases of the respiratory tract, conjunctiva and skin.

The prevention of allergies was recognised as another priority by the OSH experts. The related diseases and health effects, especially respiratory problems, make up a high proportion of recognised diseases and health effects linked to exposure to biological agents.

The sectors and occupations at risk are the agricultural and fisheries sector, the food industry, the woodworking and metalworking industries, and occupations in waste treatment plants. Well-known allergenic diseases identified in this review are asthma among farmers and farmers' lung (hypersensitivity pneumonitis). These are followed by allergies to laboratory animals, allergies resulting from working with wood and allergies due to bacterial or fungal contamination of metalworking fluid in the metalworking industry. For many occupations, however, the exact agent or substance causing the allergic reaction is not yet known. In these areas, the risk is often not limited to one biological agent but relates to a number of different agents and a range of possible triggers, further increasing the risk of disease.

The identification of allergens linked to exposure to biological agents and their differentiation from chemicals agents is the most challenging issue identified in this review — although it is the most researched issue — as the exact cause of the allergy at the agent level cannot be easily identified. In the literature on allergenic agents, a differentiation between chemical agent and biological agent is not normally applied, although there are cases in which a link between a substance originating from microorganisms and allergenic effects is elucidated. Some of the main causes are identified in Section 3.2 of this report and include moulds in buildings, flour dust, industrial enzymes, and specific bacteria occurring in specific sectors such as wood processing and metalwork. Other main triggers, such as organic dust, are referred to in Section 3.1 of this report.

Although diseases related to allergens originating from exposure to biological agents are among the most prevalent occupational diseases identified in the literature review as well as in the data extracted from monitoring systems, the exact causes are very rarely referred to in the statistical reports that are publicly available, with the exception of organic dust and farmers' lung, and the proportions of occupational diseases referred to (generally grouped across all causes, e.g. hypersensitivity pneumonitis) are merely estimated and cannot be retrieved from the official statistics. However, the statistics do refer to diseases exacerbated by exposure to biological agents and related substances, and therefore do, in some way, recognise the multifactorial nature of such diseases. This does challenge the principle of recognition of occupational diseases, that there has to be an identifiable unique cause at the origin of the disease. On the one hand, recognition of these diseases is important to assess the extent of the OSH problem and trigger prevention; on the other hand, more efforts are needed to identify the exact causes, to organise more targeted prevention.

Recommendations

Some experts recommended that, to learn more about the causes, allergic disorders, for instance asthma in agricultural settings, should be monitored and registered. Health complaints may be too unspecific to be interpreted as related to work, and the sectors could actively search for the occurrence

of work-related health problems linked to sensitisation. One of the priority activities of the Finnish occupational health services for agriculture, for instance, is preventing farmers' lung.

Data from health surveillance could also be used to identify causes, and groups of workers, occupations and sectors that are more at risk. Indeed, this is one of the elements of the successful approach adopted by the Finnish occupational health services for agriculture; this approach has resulted in an improvement in the figures for farmers' lung and has helped resolve problems in specific cases in which those working on farms have already had health problems. The results of health surveillance are used to adapt workplace measures on farms together with farmers; .a combination of technical and occupational health expertise seems to be a success factor in this respect. Agricultural technical experts are trained by occupational hygiene experts to follow the changes in technology and organisation on the farms (Louhelainen, in EU-OSHA, 2018), an approach that proved to be successful and probably facilitates communication between consultants and farmers, a normally hard to reach community.

Indeed, according to the Biological Agents Directive, workers must be able to undergo, if appropriate, relevant health surveillance prior to exposure and at regular intervals thereafter. Those arrangements must be such that it is possible to implement individual and occupational hygiene measures directly. If a worker is found to be suffering from an infection and/or illness that is suspected to be the result of exposure, the doctor or authority responsible for the health surveillance of workers must offer to closely monitor other workers who have been similarly exposed, which means that, if a worker is found to be allergic in certain work circumstances, other workers could be offered a more thorough assessment of their health status to identify causes and implement prevention measures. Employers could be reminded of this obligation, and it could be more widely applied to identify and monitor workplaces in which health problems have occurred, to identify the root causes and to ensure that prevention measures are directly implemented.

In the Netherlands, for example, efforts to protect slaughterhouse workers from respiratory problems via organic dust exposure were reported. Dutch experts also recommended a combination of organisational, technological and hygiene measures to prevent the very high rates of sensitisation in laboratory workers working with animals. A differentiation between 'clean' and 'dirty' areas (black-white areas) was one aspect covered. The experts stressed the importance of 'thoroughness' in setting measures for working with laboratory animals. The measures also covered clients and visitors. Such a combination of measures is also recommended for the waste management sector, another sector with a high prevalence of allergies.

The German advisory bodies for biological agents and hazardous substances (ABAS and AGS) have designed a joint technical rule on sensitisers that covers both biological and chemical agents. The technical rule provides details on workplace risk assessment, prevention measures and other obligations, such as the protection of vulnerable groups. A similar pragmatic approach could be taken in other countries, and experts from both areas could cooperate to design prevention measures for diseases due to exposure to biological agents.

Guidance and limit values have also been defined for some of these agents, namely flour dust, moulds and organic dust, and they are referred to in Section 3.2. An approach based on an acceptable risk level is suggested in Section 3.5.3, as the proposed threshold levels for allergens may be too low to be measured.

It should also be noted that some groups of workers were identified as particularly susceptible to some workplace allergens, and prevention should be enhanced for these workers. Workplace risk assessment needs to specifically target these workers, and specific prevention measures need to be established to protect them. In the focus group sessions, for example, groups that are vulnerable to exposure to organic dust were identified as being pregnant women; people with pre-existing diseases and conditions, such as lung diseases, allergies and asthma; people who suffer from diabetes (because of the increased risk of infection); and people with (other) chronic diseases. As organic dust was recognised as a priority issue in both animal-related occupations and waste treatment, the vulnerable groups are similar in both sectors.

Furthermore, some databases, such as the MEGA database in Germany and FIOH's FINJEM in Finland, hold data on exposure to some allergenic factors, such as organic dust and textile fibres, especially in highly exposed sectors such as waste management. Exchanging these data would facilitate the identification of groups at risk and help establish targeted prevention measures. Collecting samples on farms, for example, could help elucidate the causes and assess the prevention measures that have been taken or the impact of changes to work procedures. As measurement methods regarding biological agents are scarce, such an exchange could facilitate technical developments in this area.

The alert systems in place in some countries could also be valuable tools in identifying potential causes of allergies linked to exposure to biological agents, and some of the examples from these systems referred to in the literature review and in Section 3.5.1 actually relate to sensitisation. An exchange of data between countries could help identify such cases and elucidate the root cause. As the contribution of occupational exposures to allergic diseases is not easy to define, cooperation between occupational physicians and general health practitioners, as well as pulmonologists and dermatologists, would be beneficial. Awareness-raising among other medical professions on the possibility of exacerbating pre-existing health problems such as asthma through work would also contribute to better recognition and prevention of these diseases.

Furthermore, it should be noted that Annex III to the Biological Agents Directive (a list of classified biological agents) gives a separate indication of cases in which biological agents are likely to cause allergic or toxic reactions. Endotoxins are also covered in Section 3.2.4 of this review, in which guidance values for endotoxins and measurement results for endotoxins in some countries are referred to. Exposure to endotoxins and groups at risk from this exposure are another area that urgently needs more research and monitoring so that systematic prevention approaches can be designed. One of the areas highlighted in the research regarding exposure to endotoxins was the textile industry.

Advantages and drawbacks of pre-screening and allergy testing

With regard to allergens, early detection of sensitised workers by means of periodic screening can potentially be a valuable tool. However, the feasibility of periodic screening should be considered on a case-by-case basis, because periodic screening is of value only when accurate, reliable tests are available (Health Council of the Netherlands, 2008). Such tests are available for certain well-known allergens (such as flour dust, the urine of laboratory animals and latex) but need to be developed for others. In addition, periodic screening would need to be made cost-effective. As a successful example of health surveillance, the experts suggested screening (future) workers for existing allergies or health problems, similar to the triage method for sensitisation (which can lead to future allergies and work-related asthma), as developed and applied to bakery workers in the Netherlands. The downside of screening, however, is the possible health effects on the worker when performing the tests involved, and the fact that people may lose their jobs based on the outcome of these tests.

Adapting workplaces instead of applying pre-screening to workers selected according to their sensitivity is conceivable. For example, in Finland, the health screening included in the intervention of the OSH services on farms includes workplace adaptation, for the purpose of improving the conditions of the farms and the conditions of the workers affected. In conclusion, health surveillance should be linked to preventive measures to prevent health outcomes due to biological agents rather than the selection of workers who may resist in unhealthy conditions.

An example of the development of a (technical) solution in which a combination of organisational, technological and human factors is taken into account was the implementation of far advanced

compartmentation with strict cleaning and clothing regimes and good ventilation in a laboratory animal facility in which laboratory animal allergy was observed, and in which the same rules applied to both personnel and visitors. Similar approaches apply in other areas such as waste management, and proper facilities need to be provided for workers to ensure that procedures such as hand washing, decontamination of work clothing and disinfection can be carried out. In quite a few areas in which biological agents may occur, work clothing may be provided or may need to be separated from workers' own clothing, owing to the infection and growth potential of biological agents. One area in which this should be applied and may not be done consistently is the farming sector. This was mentioned by several experts in the review. For sensitised individuals and vulnerable groups identified by, for example, health checks for farmers — as applied in the Finnish occupational health services for agriculture — in particular, this measure could become quite important, as it would help preserve their health and work ability. Respecting these hygienic measures is also important, to help avoid the spread of zoonoses at source.

Prevention of needlestick injuries identified as a priority

Needlestick injuries and the transmission of blood-borne viruses were a topic widely addressed in the literature survey and by the OSH experts and practitioners; this topic, although mostly related to the healthcare sector, was also discussed in relation to other sectors, for example, the waste management sector. Medical procedures that pose an injury risk are those executed with sharps and needles, but they can also be caused by catheters, for example in cardiological interventions. The risk of contracting blood-borne viruses is also elevated in home care, when clients may informally be offered support, or when needles are disposed of in private homes.

The Dutch experts related needlestick injuries to the limited use of safe needle systems in the healthcare sector and by patients. This is for a variety of reasons. The availability of these systems on the shop floor can be an issue, which is related to both the purchasing policy of the employer (safe needle systems are usually more expensive) and what the supplier/producer has on offer. Sometimes it is not possible to use a safe needle system, for example when a longer needle is needed. Taking blood, for instance, is still not performed with safe needle systems. For some applications, such as flu vaccinations, no safe needle system is (yet) available.

Recommendations

In addition to safe needle systems, the prevention measures proposed by the OSH experts involved in this review included risk education/information regarding biological risks; the development of protective clothing and equipment; and vaccination rules for professional caregivers. National surveillance of accident types and the circumstances surrounding blood-related infections, prioritising the prevention of risks, was also proposed. The availability of safe needle systems is an issue; therefore, the experts considered that interventions at the level of the providers are also needed. Awareness needs to be raised at the management level of healthcare establishments, particularly among those operating in

mobile care and home care, of the need for preventive measures, the use of safe needle systems and the safe handling of waste. The experts also commented that EU-level policy action is necessary, in addition to regulations at the national level. Lastly, the experts highlighted the need to raise awareness among those who purchase needles for private purposes as well as those who dispatch the needles to users of the risks of improper waste disposal. Including pharmacies in the awareness-raising approach may be crucial.

Another aspect that was touched upon by the French experts was the fact that accidents are more likely to occur in environments where work pressure is high, and this may indirectly contribute to the high numbers of needlestick injuries in some sectors, together with a lack of awareness and training among temporary or non-expert staff, such as cleaners and workers in the waste management sector. This is also addressed in the German TRBA 400 on risk assessment for biological agents (ABAS/BAuA, 2017). The document specifically includes a section related to stress and stressors as an issue to consider in risk assessment, as stress may also have an impact on the immune status of workers, and the technical rule proposes considering organisational measures to address stress.

It is worth noting that needlestick injuries are covered by EU Directive 2010/32/EU on the prevention of sharps injuries in the hospital and healthcare sector, which implements the Framework Agreement on prevention from sharp injuries in the hospital and healthcare sector signed by the European social partners HOSPEEM and EPSU on 17 July 2009. The agreement has been followed up by an EU-financed project, with a number of recommendations in line with the ones stemming from this review. It has to be noted that the directive only applies to one sector at risk and that the same vigilance should be applied in the other sectors at risk mentioned in this review. In addition, the reports from the project, mentioned above, also highlight staff who are not permanently employed, such as trainees, students or interns, newly employed workers, temporary agency staff, and part-time staff working only at the weekends or at night, as groups at risk because of their limited access to training and information, and by the fact that they may be excluded from the interventions of OSH services and workplace risk assessments. This observation is very much in line with the findings of this review, in which the risk to trainee nurses and medical staff was highlighted, and the literature survey, as well as in the interviews with the OSH experts. In the light of the figures mentioned in these reports and the finding that needlestick injuries are severely under-reported in the healthcare sector as well as in other sectors, action at the level of enterprises and providers is urgently needed.

Travelling patterns and increase in occupations that involve travelling or contact with travellers

The increases in travelling for work, migration and travelling abroad have an impact on the potential exposures of workers to infections, including diseases that are not endemic in Europe. Occupations that involve travelling or contact with travellers were considered of concern because of the risks arising from travelling to endemic areas and the potential spread of diseases. The types of workers at risk of contracting diseases similar to those among leisure and business travellers are transport staff and workers at borders (e.g. airline personnel, customs officials), global trade workers, workers in war zones, epidemic control (field) workers, epidemiologists, journalists and media professionals. The risk of infection with hepatitis E is of particular concern for this group. Other diseases of risk for travellers are avian flu, Q fever, dengue fever, Ebola/Marburg virus infection, tularaemia, *Legionella*, measles, tuberculosis, yellow fever, SARS, cholera and meningitis. It should be noted that workers in these occupations are more at risk because individuals may differ in their level of immunity; for example, Western people may lack protective immune proteins against a biological agent in Africa.

The fact that vaccination programmes for diseases such as pertussis and malaria, which are most commonly associated with developing countries, now exist in EU Member States suggests that some countries (e.g. the Netherlands and the United Kingdom) recognise the importance of (work) travel in relation to the distribution of diseases within the EU region. However, a more systematic assessment of the spread of such diseases and potential exposures would help set out a more systematic approach to the prevention of such diseases. Existing systems, including those in the public health area, that record specific diseases, such as tuberculosis, could be scrutinised to identify workplace issues and trends in specific professions. The experts involved in this review recognised that many of the professions included in this group are not subject to the usual monitoring provisions and that diseases may not be recorded for them, making it difficult to trace any infections or trends in specific groups or occupations

back to their origin. This is also an important issue to consider in the current context of discussions on the global spread of serious diseases. Some of the alert systems identified in this review (for example the RNV3P system in France or the SIGNAAL system, developed in Belgium and the Netherlands), however, could help identify emerging diseases, as they also collect case information and include a thorough assessment, such as data mining and a literature search, to validate such cases. Again, cooperation between public health and OSH authorities could be beneficial in that respect.

Response systems for emerging biological risks that include OSH are urgently needed

From the information gathered in this review, on average, the monitoring of diseases and the alerting of new risks from biological agents do not seem to occur widely and, in some instances, are even scarce. This may be due to a general lack of knowledge and awareness of exposures to biological agents and related health problems, which in turn hinders the identification and awareness of (emerging) biological risks among (occupational) physicians and other OSH professionals responsible for reporting these risks, as well as among employers and workers.

No system is available on either the national level or the international level that enables various stakeholders to respond quickly when an emerging risk is first noticed. Several experts claimed that, although a great deal of important knowledge exists, this knowledge is not easily accessible. Furthermore, because this knowledge is not combined into one system, it is difficult to obtain a complete overview of the current situation. There are no warning systems or obligatory reporting schemes for emerging biological risks in place at either national or EU level. As a result, a rapid response in the event of an emerging biological risk is often not possible, which in turn may result in the biological risk spreading quickly and, in extreme cases, an epidemic. For example, French experts explained that a number of monitoring systems that collect notifications of such diseases do exist, mostly in the area of public health, but the information is not centralised and therefore not easily accessible; a link to OSH is also missing. These systems cover specific infections, in particular zoonoses, and some coincide with priorities identified in the occupational field, such as the increase in tuberculosis infections and tropical diseases, and the increasing number of outbreaks of legionellosis. Some of these systems were installed in the public health field to improve prevention for groups of workers that are not sufficiently covered by occupational disease registration systems. This is the case for systems that record cases of brucellosis, for example, which are relevant to agriculture, a sector with a high proportion of self-employed and family workers. If warning systems such as epidemic warning and monitoring systems (for instance the Euro Flu Net approach mentioned by the French experts or the obligatory reporting schemes for certain zoonotic or infectious diseases) are not in place and do not link up with OSH institutions, workplaces and sectors are very likely to be deprived of the means to react promptly to outbreaks such as those of BSE, foot-and-mouth disease and avian flu, or the increase in nosocomial infections with multi-resistant organisms. Such events are likely to arise again, and it needs to be ensured that the response includes OSH considerations beyond the mere provision of PPE, as in the case of the COVID-19 epidemic.

As indicated in the descriptions of monitoring systems that include emerging risks, the detection of emerging risks may also require different instruments from those used for monitoring known occupational diseases. Several complementary methods are considered necessary for the detection of emerging risks, such as epidemiological studies, health surveillance studies and the evaluation of cases, ideally carried out by an (international) team of experts. The identification of new and/or emerging risks could be part of the regular monitoring system of occupational exposures and/or diseases, and could be based on the evaluation of a case by a (international) team of experts using, for example, their national experience, data mining and literature searches, as is done in the French RNV3P system. Such an approach is proposed by the Modernet occWatch system ([45]), which registers cases across countries. National alert and sentinel approaches are explored in more detail in another study commissioned by EU-OSHA, which analysed such systems in more depth and provided recommendations in this respect (EU-OSHA, 2018b).

([45]) OccWatch (https://occwatch.anses.fr/node/10) stands for 'Occupational Diseases Watch'. It is a sentinel clinical watch system dedicated to highlighting newly occurring occupational diseases. OccWatch sentinel clinical system is powered by ANSES, the operator of the rnv3p system, which developed for several years a specific approach to handling new work-related diseases.

A network of professionals from (occupational) health services who participate in multidisciplinary teams (veterinarians, GPs, occupational physicians) could be provided with support for the rapid exchange of information for the prevention of zoonotic diseases, for instance. The multidisciplinary composition of the group is considered one of the key factors facilitating early recognition, although it may be time-consuming to operate such a system. The Dutch and Danish experts also called for stronger participation of sectoral organisations, which could investigate their own sectors and facilitate epidemiological studies. Systems such as the SIGNAAL and RNV3P sentinel systems could be useful for collecting and validating first alerts, and could help to rapidly initiate additional epidemiological or intervention studies to investigate health problems and how to prevent them at the workplace level. In addition, the development of a warning system for emerging biological risks should be combined with an action plan aimed at a rapid response to minimise the risks due to biological agents in the workplace. Contingency plans and approaches need to be coordinated with other ministries (health, migration or internal affairs, agriculture, etc.), and it is important that the protection of workers is recognised as a priority in these approaches.

In some countries, GPs are also involved in the registration of occupational diseases and could, for instance, cover the cases that are not picked up by occupational physicians and other occupational health professionals.

Another source of information could be regional health authorities (e.g. those involved in vaccination programmes for travellers) and microbiological laboratories that encounter, for instance, cases of infectious diseases for which a relation to work might be expected.

All experts participating in this study agreed that a lot of awareness-raising about the risks linked to exposure to biological agents at work was needed, not only among OSH stakeholders, employers and workers, but also among a wider audience that includes policy-makers, including those in public health, the medical community beyond occupational physicians, with a particular emphasis on GPs, pulmonologists and dermatologists as well as those dealing with infectious diseases, and the general public. Recent pandemics provide an opportunity for a wider debate, and this aligns with the call of several experts for cooperation with the media and other communities that can contribute to such a debate.

Use of health surveillance data

Health surveillance of workers exposed to potential hazardous exposures is another source of information that could be used and in at least one country such information is reportedly included in the assessment of reported occupational disease cases. There are examples where health surveillance data were successfully used, such as the initiatives by the Finnish OSH services for the farming sector. The effectiveness of screening practices for diagnosing occupational asthma or identifying at-risk individuals were improved gradually and that includes the revision of the guidelines on screening practices in different sectors, including food production, agriculture biotechnology and animal-related work. Also, in Finland, IgE and IgG antibodies are measured among workers as indicators of worker exposure.

Health surveillance data could be used to identify first cases of health problems or diseases in workers too, as mentioned in section 3.5.2 and above related to allergens. The biological agents Directive does grant each worker for whom workplace risk assessment reveals a risk the right to undergo, if appropriate, relevant health surveillance such an extent that it is directly possible to implement individual and occupational hygiene measures. It should help identify those workers for whom special protective measures may be required, and health surveillance has to be offered to other workers who have been similarly exposed. A reassessment of the risk of exposure must then be carried out and an individual medical record must be kept for at least 10 years, following the end of exposure. Information and advice must be given to workers regarding any health surveillance that they may undergo following the end of exposure. This type of documentation may provide an opportunity to follow up on some exposures and should help protect workers in cases of emerging health problems. More awareness of these provisions could be raised at the workplace level and among OSH experts.

4.1.1 Prevention at enterprise level

Generally, the sectors described by the experts as having measures in place related to risks due to biological agents were the healthcare sector, laboratories, the agricultural sector, the woodworking industry, the meat industry, sewage systems and day-care centres. The majority of these policies are aimed at preventing specific diseases among workers, such as respiratory diseases (e.g. asthma, farmer's lung), infectious diseases from bacteria or viruses (e.g. MRSA, Ebola, BSE, influenza, tuberculosis) and blood-borne infections (e.g. hepatitis B infection, HIV infection), and thus do not seem to cover the whole range of risks due to biological agents that were identified through the literature review and the interviews with experts in these sectors. They seem to focus mainly on situations with a clear risk of infection and, to a much lesser extent, biological risks arising from unintended exposures.

Overall, the policies and prevention measures described by the experts regarding all sectors were successful in their implementation and effectiveness. Most were transferable, according to the experts, although some adaption is recommended to ensure a good fit with the situation in question. Reported success factors were effective OSH services, systematic health surveillance and systematic exposure assessment (for instance in a particular sector or aimed at a particular group of workers), cooperation between stakeholders at the regional level, and involvement of and/or cooperation with other specific key intermediaries (such as pharmacists, GPs and veterinarians) to reach specific target groups (e.g. famers). Other factors that were considered important for policies to be successful were good national visibility and approachability of experts, the availability of research results and reports, lobbying groups, media attention and public awareness. Raising awareness of the topic among workers as well as developing appropriate (technological) solutions is also considered very important.

However, the reality is that there is a lack of effective methods for collecting quantified data; a lack of a clear reporting system for emerging diseases and risk situations at the local and national levels; and a lack of collaboration between ministries, expert organisations and other relevant stakeholders.

The policy measures described were often aimed at preventing disease among workers, although sometimes the aim was to reduce worker exposure to biological agents. Prevention of disease leads to approaches that are different from those used for prevention of exposure: for example, vaccines may prevent disease, while technical measures and protective clothes may prevent exposure. The other goals of the policy measures were a better understanding or control of situations and reducing accidents at work.

The policies in place were primarily a mix of individual (worker) and collective technical and/or organisational measures. In the interviews, the success factors mentioned most frequently for implementation, application and awareness-raising were:

- a good fit with the target group in terms of content, distribution and organisation (they are practical and relevant);
- involvement of highly motivated and/or interested target groups and intermediaries (experts, organisations, management), preferably from the start;
- cooperative target organisations;
- organisations feeling responsible for improving working conditions;
- real-time feedback from experts in the workplace, followed by immediate action (e.g. an expert observes the work process and provides tips for safer work);
- sufficient resources;
- expert organisations working together with a shared goal;
- national attention (which leads to the development of legislation/technical rules at national level);
- the translation of national measures into practical guidelines;
- systematic inspections;
- a combination of awareness-raising and training with guidance and practical advice;
- increasing awareness of risks and prevention measures regarding biological agents in specific sectors or among the general population.

For effective dissemination, communication channels and intermediaries that meet the needs and speak the language of the target audience must be chosen. One example is the Finnish OSH services that visit farms on a regular basis to discuss a broad range of OSH topics.

The most significant obstacles to good prevention mentioned by the experts and workplace practitioners were:

- a lack of awareness of health risks within the target group;
- a lack of resources to implement prevention measures;
- communication problems with the target group;
- not working together to achieve a shared goal;
- a measure negatively affecting work or work comfort (for instance with regard to the use of PPE);
- the measures being designed not to protect workers but to improve the quality of the final product (for example in the food industry) or patient safety (for example in the healthcare sector).

Furthermore, there might be a lack of evidence of the risk of exposure to biological agents in a workplace, and therefore it may not be obvious to workplace actors such as employers, that measures need to be taken. In addition, a continuous effort to improve workplace protection as postulated by OSH legislation was seen as lacking; a prevention measure might be implemented once but not updated, and there may be no follow-up to check its proper implementation.

Current policies showed several limitations as well. Firstly, small companies were reported to be less interested in prevention than large companies, and small companies are also harder to reach and less aware of risks. Secondly, measures often do not take into account the exposure route (e.g. dermal exposure, inhalation); this lack of specificity may result in less effective policy measures. A systematic approach to the design and implementation of OSH policy is advisable, as well an analysis of the potential obstacles and success factors prior to implementation so that a targeted implementation strategy can be developed to ensure the policy's purpose and objectives are met. Attention should be paid to factors at the level of the policy itself, the potential user and parties involved, the organisation, the socio-political context and the implementation strategy.

Respecting the hierarchy of prevention measures

Although these prevention measures are low in the hierarchy of control measures that forms part of the legislative framework, it was observed that, in relation to requirements for the sufficient protection of workers, many of the preventive measures mentioned by the experts were individual measures (for example prescribing or monitoring the use of PPE) or vaccination, rather than measures linked to a general prevention approach. The hierarchy of control measures prescribed by EU legislation sets out the requirement that the risk should be eliminated altogether and only if it cannot should collective organisational or technical measures be taken, and, as a last resort, individual measures such as PPE. What is commonplace in the management of chemical risks should also be commonplace in the approach to the prevention of workplace risks from biological agents.

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According to the Biological Agents Directive, when the results of a workplace risk assessment reveal a risk to workers' health or safety, workers' exposure must be prevented. When this is not technically practicable, the risk of exposure must be reduced to as low a level as necessary in order to protect workers, in particular by:

- keeping the number of workers exposed or likely to be exposed as low as possible;
- designing work processes and engineering control measures so as to avoid or minimise the release of biological agents into the place of work;
- establishing collective protection measures and/or, when exposure cannot be avoided by other means, individual protection measures;
- ensuring that hygiene measures are compatible with the aim of preventing or reducing the accidental transfer or release of a biological agent from the workplace;
- using the biohazard sign and other relevant warning signs;
- drawing up plans to deal with accidents involving biological agents;
- testing, when it is necessary and technically possible, for the presence, outside the primary physical confinement, of biological agents used at work;
- ensuring the safe collection, storage and disposal of waste by workers, including the use of secure and identifiable containers, after suitable treatment if appropriate;
- ensuring that arrangements are in place for the safe handling and transport of biological agents within the workplace.

Hygiene measures

In addition to the technical and organisational measures, the directive specifies that appropriate hygiene measures need to be taken. Employers should ensure that:

- workers do not eat or drink in working areas where there is a risk of contamination by biological agents;
- workers are provided with appropriate protective clothing or other appropriate special clothing;

- workers are provided with appropriate and adequate washing and toilet facilities, which may include eye washes and/or skin antiseptics;
- any necessary protective equipment is:
  - properly stored in a well-defined place,
  - checked and cleaned if possible before, and in any case after, each use,
  - is repaired, if defective, or is replaced before further use;
- procedures are specified for taking, handling and processing samples of human or animal origin;

- working clothes and protective equipment, including protective clothing, which may be contaminated by biological agents, are removed when workers leave the working area and, before carrying out the measures referred to in the second subparagraph, kept separately from other clothing — the employer must ensure that such clothing and protective equipment is decontaminated and cleaned, or, if necessary, destroyed.
- workers may not be charged for the cost PPE, its storage and cleaning of work clothing.

One topic that was discussed extensively by the experts and workplace practitioners was the availability and appropriateness of PPE, as well as the fact that workers have to use the same PPE for long periods of time. They recommended the provision of additional information and training, and the opportunity for employers and workers to try PPE in a supervised way, to ensure a good fit with their practical needs.

Differentiation between 'clean' and 'dirty' areas (black-white areas) was also considered important by the experts and practitioners involved in this review, as it avoids the spread of contamination in sectors such as waste management, farming and health care, but issues linked to work clothing may also be relevant to other occupations such as border staff and transport workers. This is generally relatively simple to implement/organise and can be applied in many of the sectors/occupations that are considered of concern with regard to risks due to biological agents. In addition, the availability of areas for changing work clothing and washing clothing, etc., is considered an issue.

Many of the measures that were mentioned by the experts and workplace practitioners (black-white areas, measures to avoid dust, organisational measures to separate workers from the exposure) are laid down in legislation and need to be applied in workplaces where exposure to biological agents is possible; this includes unintended exposures. More awareness has to be raised about the legal framework, and it has to be urgently applied, respecting the hierarchy of control measures. Measures that seem to be commonplace for chemical exposures also need to be implemented for biological agents.

Vaccination and how to address low vaccination rates

Vaccination was a prevention measure that was mentioned many times by the experts involved in this review, for example regarding exposures in health care, waste management and animal-related professions. Germany, for example, referred to its policy in the healthcare sector to protect workers, company doctors and employers in hospitals and day-care centres from infection from pathogens such as hepatitis B and those that cause children's diseases, zoonotic pathogens and those that cause exotic and tropical diseases. The Netherlands and the United Kingdom have vaccination programmes for diseases such as pertussis and malaria, which are most commonly associated with (visiting) developing countries. The experts also raised issues such as the risk of contracting measles, especially for vulnerable health workers and trainees. Vaccination was also mentioned as an issue in the protection of the armed forces, in particular those that are stationed abroad, against hepatitis B infections.

It is worth noting that Annex III of Directive 2000/54/EC on the protection of workers from the risks of exposure to biological agents provides information on the agents for which effective vaccines are available, and those agents have a specific notation in the list in this annex. The agents are listed in Section 3.1.2 of this report and cover a wide range of microorganisms. In addition, according to the directive, workers should be informed of the benefits and drawbacks of both vaccination and non-

vaccination, and vaccination must be offered free of charge to workers, according to the directive. Which vaccinations are offered and whether or not they are a requirement for carrying out a certain job is left to the Member States to decide.

Quite a few of the sectors considered in this review would benefit from vaccinations being offered to workers and effectively applied. However, the experts' observation about the low vaccination rates, particularly in the healthcare sector, is in line with the results of the literature survey. They concluded that awareness-raising and appropriate information were needed among workers, and that employers needed to raise vaccination rates where it would help to implement better protection of workers.

Nevertheless, there were contrasting views with regard to whether or not there should be obligatory vaccinations, for example for healthcare workers. Although in one country these are required to carry out work, in another country experts wanted to strongly recommend them rather than create an obligation. Furthermore, doubts were raised as regards the reasons for imposing vaccinations, as it was considered by some that, in health care, it was more patient protection than worker protection that was behind. As already stated in the literature review (EU-OSHA, 2019a), the reasons for the low vaccination rates still need to be elucidated. The French experts also considered that there is a need to bring the healthcare issues to the attention of national decision-makers and promote awareness of, for example, low vaccination rates. The importance of effective vaccines might have been underlined, however, by the current coronavirus epidemic, and it remains to be seen whether or not this will have an influence on vaccination rates in the future.

Training and information crucial

The provision of training and information was an important issue raised by all the experts in the qualitative research, as they highlighted a particular lack of awareness in most of the occupations regarding biological agent-related issues. A number of training and awareness-raising programmes were therefore mentioned. The INRS, for example, provides advice on how to prevent risks from biological agents in the workplace through a network for the prevention of occupational accidents and diseases. One successful INRS initiative is a training programme that promotes risk awareness and the assessment of biological agents at work and covers all diseases and sectors (except the health sector). The training is organised every year, and participants learn how to perform a workplace risk assessment. One success factor is that the training is practical and simple, and therefore suited to people with no background knowledge of biological agents. Moreover, the training is tailored to the occupational sector, which helps identify the concerns of workers and other enterprise actors. Although the training is effective, workers tend to think that information on biological risks is relevant only to physicians. The training is actually open to audiences of all sectors, but there is resistance to change. Unfortunately, how trainees apply the knowledge gained during the training has not been assessed.

Finland also offers strategic training for occupational healthcare professionals (including nurses and other OSH experts, such as physiotherapists and psychologists in occupational health centres) in all sectors and industries in which exposure to biological agents is possible. The training is provided by FIOH, which is recognised by employers as a competent organisation. As the field is constantly developing, cooperation and research regarding this topic are needed. It was regarded as important that new knowledge is disseminated among the OSH professionals as well as at the workplace level. The training is also regularly provided to occupational health services in the farming sector, for example; this ensures that knowledge reaches workplaces in a sector that is normally difficult to reach and that new measures are implemented in workplaces. In this way, the rates of farmers' lung, for example, could be decreased and considerable improvements could be introduced. The training also ensures that occupational experts are informed about changes to technology on farms.

Some of these examples could be followed in other countries and an exchange of experiences could be beneficial, as all the experts shared concerns about the very low level of awareness and knowledge in most of the sectors.

Unintended exposures need to be addressed by applying general prevention principles

As mentioned above, the experts observed that many of the preventive measures and policies applied were focused on specific biological agents and there was not enough account taken of unintended exposures. Unintended exposure is considered a serious issue, as the related risk of exposure is not

always obvious. Since some of the health effects related to biological agents are rather unspecific, it is hard to estimate how frequently exposure to biological agents leads to disease. Many of the occupations at risk identified in this review involve a considerable part of unintended exposures, as workers may be exposed to biological agents which originate from the work process or materials used in the work process, without the biological agent being deliberately used during work tasks (which could be the case, for instance, in a biotechnological process to produce enzymes, in vaccine production, in the production of antibiotics, in some research labs or in food production).

As mentioned earlier, whenever people are in contact with the natural materials or those of human or animal origin, foodstuff,as well as waste and wastewater, they may be exposed to biological agents:

These exposures occur in many of the professions referred to in this report, and it is often unclear to which specific biological agents workers may be exposed. The exposures also depend on many other factors, such as work procedures, the materials used and climatic conditions, which influence the growth conditions of microorganisms.

To address these exposures, as mentioned before, approaches can build on existing experiences. To support their workplace risk assessment, employers rely on available information, including:

- the classification of biological agents that are or may be a hazard to human health;
- recommendations from a competent authority that indicate that the biological agent should be controlled in order to protect workers' health, when workers are or may be exposed to such a biological agent as a result of their work;
- information on diseases that may be contracted as a result of work;
- information on potential allergenic or toxigenic effects as a result of work;
- knowledge of a disease from which a worker is found to be suffering and that has a direct connection with his work.

It would be possible to build on different national approaches that address unintended exposures. Unintended exposures may be at least pre-empted to some extent, as information from existing exposure assessments (e.g. based on data from the MEGA database, the GESTIS Biological Agents Database, FINJEM, COLCHIC and other sources) and research, such as the results of this review, could be shared to allow employers to gain an understanding of what the relevant exposures in terms of agents and circumstances may be, and to develop guidance, tools and similar work instructions or guidance sheets to those developed by chemical risk assessment tools.

In Germany, when working with biological agents, a differentiation is made between activities with and without safety level classification. This is because of different approaches to risk assessment. A differentiation is also made between targeted and non-targeted activities. In the case of targeted activities, the safety level depends on the risk group of the biological agent to be determined. In the case of non-targeted activities, the safety level classification is specified by the risk group of the biological that determines the risk of infection. Other activities are called 'non-safety level activities', for example cleaning and refurbishment work, activities in the areas of veterinary medicine, agriculture, forestry, wastewater management and general waste management, and activities in biogas plants and abattoirs. The TRBA and 'Resolutions of the Committee for Biological Agents (ABAS) on requirements for activities with biological agents in special cases' are something between prescriptive legislation and a risk assessment aid that frames work in certain occupations and tasks. Some of these TRBA are available in English and are regularly updated to reflect recent findings and developments. The TRBA are developed by an expert committee and its subgroups, in which representatives of social partners and the sectors concerned are also involved. These approaches could be a basis for discussions in other countries, with the aim of developing sectoral and risk-based guidance targeted at biological agents. Another tool developed in Germany and described in this review is the GESTIS Biological Agents Database, which provides information on 15,000 biological agents and many occupations and tasks that involve exposure to biological agents. It provides information broken down by sector and occupation, including information on specific biological agents that workers can be exposed to.

The steps needed to remove or reduce the risks to workers will depend on the particular biological agent, but there are a number of common actions that can be applied:

- Many biological agents are transmitted via air. The formation of aerosols and dusts should therefore be avoided, including when cleaning and during maintenance.
- Good housekeeping, hygienic working procedures and the use of relevant warning signs are key elements of safe and healthy working conditions and should be applied consistently in all areas and for all tasks, including waste storage and disposal, cleaning and maintenance.
- Many microorganisms have developed mechanisms to survive or resist heat, dehydration or radiation, for example by producing spores. Decontamination measures for waste, equipment and clothing, and appropriate hygiene measures for workers that include instructions for the safe disposal of waste, emergency procedures and first aid, should be established.
- In some cases, preventive measures include vaccination being provided to workers on a voluntary basis.

Prevention measures regarding unintended use of biological agents could be built on those set out for intentional use of biological agents in other sectors, for example farms learning from approaches in the healthcare sector, for instance regarding antibiotic resistance. In addition, there is a need for risk assessment tools that take into account the hierarchy of control measures as well as the specificities of biological agents (e.g. their ability to grow and spread, health effects, viability), for example the risk assessment guidance in TRBA 400 provided by ABAS (ABAS/BAuA, 2017), which holds information on typical exposures in specific sectors. As regards multi-exposure risks, technical solutions were suggested by the experts, for instance the automation of processes to separate workers from biological agents entirely. It is recommended that these examples be examined to see if they are applicable and effective on a larger scale and to other occupations.

Workplace risk assessment needs to take a process approach when workers are potentially exposed to biological agents. This approach traces the steps of a worker performing their tasks to discover all possible risks of exposure and obtain a complete overview of the situations in which measures are needed. For instance, when a farmer is reaping hay, dust may affect the machinery (the filter of the tractor may become clogged), and the farmer may breathe in organic dust. Farmers may bring dust home on their work clothes, resulting in not only prolonged exposure for the farmer but also the exposure being extended to, for instance, other members of the family. For all these situations, existing measures (e.g. dust-avoiding storage of hay and grain, handling and cleaning of storage areas, maintaining the filter of the tractor on a regular basis — including changing/cleaning filters — changing clothing before entering the house and regularly washing clothing, using PPE in the workplace when necessary) could be applied, and, if not, new measures could be developed (e.g. another ventilation system that does not get clogged easily and another method for reaping hay during which less organic dust is emitted).

Table 4 illustrates some of the prevention measures in sectors addressed by this review. More information can be found in the annexes to this report.

Table 4: Prevention measures in specific sectors and occupations

Sector/occupation	Exposures/health problems	Prevention measures
Health care	Several viral and bacterial infections such as HIV, hepatitis and tuberculosis Needlestick injuries	Safe handling of infectious specimens, sharps waste, contaminated linen and other material Safe handling and cleaning of blood spills and other bodily fluids Adequate protective equipment, gloves, clothing, glasses Appropriate hygiene measures Appropriate technical measures in isolation wards and diagnostic laboratories ([a])
Agriculture Forestry Horticulture Animal food and fodder production	Bacteria, fungi, mites and viruses transmitted from animals, parasites and ticks Leptospirosis Respiratory problems due to microorganisms and mites in	Measures to avoid dust and aerosols Avoiding contact with contaminated animals or equipment Protection against animal bites and stings

Sector/occupation	Exposures/health problems	Prevention measures
	organic dusts of grain, milk powder, flour and spices Specific allergic diseases, such as farmer's lung and bird breeder's lung	Pest and rodent control Implementing changes at the design stage Closed vehicles and equipment with ventilation Cleaning and maintenance Hygiene measures (e.g. hand washing, black-white areas for work clothing)
Waste management and wastewater management	Exposure to moulds and bacteria, causing respiratory problems and infections, diarrhoea and other digestive problems Needlestick injuries	Measures to avoid dust and aerosols Closed or automated processes, for example in waste sorting Local exhaust ventilation Closed vehicles with appropriate ventilation, for example in composting Organisational measures implemented on clients' premises (e.g. waste collection cycles) Cleaning and maintenance Hygiene measures, including black-white areas
Laboratories	Infections and allergies when handling specimens, microorganisms and cell cultures of, for example, human tissues Accidental spills and needlestick injuries Allergies to laboratory animals	Appropriate technical measures, such as microbiological safety cabinets ([a]) Measures to avoid dust and aerosols Safe handling and transport of samples Appropriate personal protection and hygiene measures Decontamination and emergency measures for spills Restricted access Biosafety labels
Food (e.g. cheese, yoghurt, salami) or food additive production, bakeries	Moulds/yeasts, bacteria and mites causing allergies	Closed processes and local exhaust ventilation

Sector/occupation	Exposures/health problems	Prevention measures
	Organic dusts of grain, milk powder or flour contaminated with biological agents	Avoiding aerosol and dust formation Separating contaminated/dusty work areas Appropriate hygiene measures
Working areas with air-conditioning systems and high humidity (e.g. textile industry, print industry and paper production)	Allergies and respiratory disorders due to moulds/yeasts Legionellosis	Measures to avoid dust and aerosols Regular maintenance of ventilation, machinery and work areas Restricting numbers of workers Maintaining high hot (tap) water temperatures
Metal-processing industry Wood-processing industry	Skin problems due to bacteria and bronchial asthma due to moulds/yeasts in circulating fluids in industrial processes such as grinding, pulp factories, and metal- and stone-cutting fluids Exposure to organic dust/wood dust	Local exhaust ventilation Measures to avoid dust Regular maintenance, filtering and decontamination of cutting fluids and machinery Skin protection Appropriate hygiene measures Cleaning and maintenance
Archives, museums, libraries	Moulds/yeasts and bacteria causing allergies and respiratory disorders	Avoiding dust and aerosol Ventilation and control of climatic conditions to avoid mould formation Appropriate storage of items Decontamination Adequate personal protective equipment
Building and construction industry; processing of natural materials such as clay, straw, reed; redevelopment of buildings	Moulds and bacteria due to deterioration of building materials	Measures to avoid dust and aerosol Appropriate personal protection and hygiene measures

Adapted from EU-OSHA (2003), with input from the review.

([a]) Specific measures proposed in the Biological Agents Directive.

Support for SMEs needed

As most European enterprises are SMEs, this is an important issue to address. Many of the sectors targeted by this review are characterised by a high proportion of SMEs, and the experts and practitioners

involved in this review have expressed particular concern regarding sectors with a high proportion of SMEs, such as agriculture. Even in structures such as health care, some branches may be organised as SMEs, for example medical practices, veterinary surgeries and dental practices. An outpatient clinic can also be an SME. The German experts, for example, highlighted outpatient clinics and home care establishments as subsectors of health care in need of OSH support and awareness. SMEs are generally less aware of risks due to biological agents, are often less easy to reach, for instance with regard to a campaign, and often have less (financial) means to implement control measures than larger companies. The difficulty in reaching SMEs is partly due to declining resources for preventing risks due to biological agents. In addition, the low number of workers in SMEs restricts the possibilities of sending workers to informative meetings or training sessions. In some of the sectors addressed by this review, the boundary between family members and workers may be blurred, for example on farms, but family workers should be included in any preventive approaches.

One proposed way to reach SMEs is to implement policy measures at the municipal level, resulting in more communication between the local government and SMEs. In addition, simple and practical tools are most useful to SMEs; these should include risks from biological agents and be provided, together with training and information, by experts to increase awareness. Currently, tools that have been used successfully can be implemented sector-wide/nationwide/Europe-wide. During the stakeholder workshop, several country-specific examples were given. In the United Kingdom, the 'SME toolbox' ([46]) — a successful, freely accessible tool that presents an overview of health and safety issues as well as risk assessment guidance — is available. The BeSmart tool ([47]) in Ireland aims to help business owners/managers prepare a risk assessment and safety statements for the workplace. The tool highlights the main hazards in a sector. In the Netherlands, Stigas provides a tool for entrepreneurs and workers in the agricultural sector. Other countries mentioned that financing was available for developing courses for SMEs and consultants visiting specific sectors that have a large proportion of SMEs (e.g. hairdressers).

Another recommendation was to make policy measures more sector specific, as sectors and regional specificities may vary considerably. For example, sectoral organisations could make an inventory of their relevant biological risks and develop their own guidelines, including recommendations on how to prevent or manage risks. Specific guidance developed together with sectoral organisations, which would be important ambassadors for the prevention message, could be an extremely successful approach.

As all Member States have similar problems with reaching SMEs and increasing their awareness, an efficient way of tackling this issue may be arrangements on the EU level.

Control-banding tools

Carrying out a qualitative assessment of biological risks in the workplace by using, for example, risk assessment tools in combination with options for control measures could be used as a first step towards reducing the risks. Existing tools/best practices could be implemented in other sectors and even at national or European level. Examples of existing tools are the blueprint for risk inventory and evaluation (RI&E) for biological agents and the guidance on allergens developed by NECORD, which were discussed in the focus groups.

Lavoie et al. (2013) propose a control-banding method for selecting respiratory protection against infectious and non-infectious bioaerosols that is applicable to all workplaces and intended for occupational hygienists and other OSH practitioners, as well as experts who are members of learned societies. This model, which is a follow-up to the *Guide on respiratory protection against bioaerosols*, published by the Institut de recherche Robert-Sauvé en santé et en sécurité du travail in 2007 (Lavoie et al., 2007), is based on bioaerosol-related knowledge and approaches to control banding developed mainly for chemical contaminants and nanoparticles. The model is presented in the form of a matrix consisting of the four risk groups used in biosafety and five exposure levels. The cross-tabulation of a

([46]) http://www.hse.gov.uk/leadership/smallbusinesses.htm
([47]) https://www.besmart.ie/

risk group and a given exposure level corresponds to an assigned protection factor that allows the user to choose an appropriate respirator.

The German 'Guideline for risk assessment and for the instruction of employees regarding activities with biological agents' (TRBA 400) (ABAS/BAuA, 2017) introduces a convention on sensitising and toxic hazards that follows a control-banding approach. It is based on an exposure matrix that links information on assumed/estimated exposure levels (without measuring) to the estimated risk that must be controlled. Exposure matrices for moulds and endotoxins in different occupations are also available, and some examples were shown during the stakeholder workshop (Förster, in EU-OSHA, 2018).

Such tools could be developed in other countries to support a more systematic approach to workplace risk assessment and prevention of exposure to biological agents. A lot could be learned from existing concepts for the assessment of chemical substances in this respect.

4.1.2 Policies across sectors and policy areas

As mentioned above, the basis for Member States' legislation regarding exposure to biological agents at work in the wider sense of the term is the Biological Agents Directive, which sets out a framework for the prevention of risks, following the framework applicable to workplace risks: workplace risk assessment, setting preventive measures following a hierarchy of control and prioritising collective protective measures over personal protective measures, information and consultation of workers, provisions for health surveillance and record-keeping. The systems applicable in the Member States build on this structure and regulate exposure to biological agents with varying levels of detail. Prevention measures specific to the risks from biological agents encompass, for example, vaccination, avoidance of infection, and specific hygiene and disinfection measures. In the previous chapters, the infection risks and sensitisation have been addressed in more detail, the risks in some important occupations and growing economic sectors have been outlined, and many of the initiatives and programmes mentioned by the experts and practitioners involved in this study were specific to a sector or occupation, or specific tasks.

Some policy measures mentioned, however, have a broader focus (see Annex 5, Table 18). In general, there are issues that are relevant to several occupations and sectors, and measures can be relevant to all of them; there are also tools or initiatives that can be applied across sectors. Some examples are outlined below.

Acting at the design stage and when developing new technologies

A lot of the exposures and health problems identified in this review could be avoided at the design stage of facilities and workplaces if exposure to biological agents were considered. This could include designing technological solutions when building, for example, agricultural facilities that address trends in production on changing breeding techniques and incorporate worker protection. Examples that were mentioned in this review were the design of a robot to catch poultry for transport, the use of dust-filtering equipment in composting and the design of waste-sorting cabins. Structural changes in sectors such as agriculture and health care should warrant a reflection on the OSH risks in newly designed work procedures and techniques. Such debates could be held at the level of the sectoral social partners, for instance, which would also be the strongest advocates for approaches that incorporate good OSH.

Taking a broader approach to prevention

Some experts in the focus groups suggested different approaches to improve occupational risk prevention.

The combined risk approach has a broader scope and includes more (diverse) risks (biological risks, physical risks, chemical risks and/or risks from multiple biological agents). It is recommended that a broader scope be considered when developing preventive measures for risks such as organic dust (which contains a variety of specific biological agents such as moulds and bacteria). Control measures do not necessarily differ between different fields (e.g. biological agents and chemical agents), and the efficacy of these measures is assumed to be comparable in controlling exposure. Therefore, considering prevention measures that are already in place to control other exposures (e.g. dust and chemical substances) may prove to be a good alternative approach or may present another opportunity to control

biological risks. While explaining that, even for professionals, it is difficult to pinpoint the exact biological agents present in any work environment, the experts suggested that the measures should be a solution for different risks altogether (biological, chemical and mechanical).

For issues occurring in several sectors in particular (e.g. organic dust, microorganisms causing multiple resistance to antibiotics, zoonotic agents), an approach similar to a lifecycle approach in environmental protection or a supply chain approach in chemicals legislation might deliver effective solutions to avoiding exposure or help set out preventive measures. Such an approach entails tracking the biological agents from their effects on human health back to the source from which they originated, which would enable action against the problem at the source and at all subsequent stages. For instance, to prevent needlestick injuries in waste-sorting centres, one measure could be to provide information early on to consumers, to prevent needles being disposed of in the general waste bin; this could be in the form of guidance for patients distributed at pharmacies on how to dispose of used needles in a safe way and providing specific needleproof waste receptacles. Such an approach is more likely to take vulnerable groups into account, as they are more likely to be identified as part of the chain of events, for instance cleaning workers in hospitals and maintenance workers in waste treatment, similarly to a supply chain approach. Other examples of supply chain approaches identified in this review include tackling the issue of resistance to antibiotics by reducing the use of antibiotics in both animal care and human care, and preventing further distribution of antibiotics in the environment (for instance via surface water) by means of waste(water) treatment.

A lifecycle approach to antibiotics use prevents exposures to multi-resistant strains

Several experts suggested that policy measures for agents with antibiotic resistance should be reinforced. This confirms earlier warnings issued by EU-OSHA after an expert forecast (EU-OSHA, 2007). The experts consulted for this review agreed that there was an urgent need to tackle the issue transversally, across sectors. The policy measures should aim to improve the prescription of antibiotics, prevent the spread of agents with antibiotic resistance from healthcare workers to patients and within hospitals, and improve immunisation. Because this problem of multi-resistant agents transcends sectors, meaning it affects several sectors and occupations, including health care and home care, the food chain, and the waste management sector, it would be best to take a comprehensive approach when developing preventive policy measures and technological solutions. All tasks and steps involved in the use of an antibiotic may lead to exposure of workers to multi-resistant strains, and this should be prevented. That is why it is important to take a lifecycle approach to the use of antibiotics and assess all the value chains in which antibiotics are used for any potential of cause microbial resistance and expose workers to multi-resistant strains. Prevention should be focused on all involved, and it should protect them during the

entire chain of events, which starts with the purchase of antibiotics and ends with disposal and waste management.

It was also suggested that farmers who seek medical care, for example, should inform the healthcare organisation if they use antibiotics in animal breeding and may be potential carriers of such organisms, and that professions that are in contact with animals should be trained in the use of antibiotic-avoiding strategies and informed of the risks. Other measures proposed were better information, education and training (for instance personal counselling with physicians) on how to recognise multi-resistant agents, alternative treatments and risk prevention. It was also suggested that cooperation between different stakeholders (e.g. farmers and veterinarians) be stimulated to develop new strategies to avoid the use of antibiotics. Another approach proposed was to conduct health checks for specific professions, for example farmers, to assess infections with multi-resistant bacteria. Again, this could be included in health surveillance programmes, which according to the Biological Agents Directive have to be offered to workers and should be linked to occupational hygiene measures. If the worker is found to be suffering from an infection and/or illness that is suspected to be the result of exposure, surveillance should be offered to other workers who have been similarly exposed, as mentioned above.

Cooperation between occupational health and public health authorities and with medical specialists other than occupational health practitioners, for example GPs, could be beneficial in avoiding the spread of such antibiotic agents. The German experts, for example, questioned whether new legislation on the use of antibiotics should be part of veterinary medicine legislation only or whether it should also refer to OSH, and discussed whether it is an issue of biological agents or hazardous substances.

Some countries, such as the Netherlands, have established expert groups that assess multi-resistant organisms and regularly report on the prevalence of multi-resistance among these microorganisms; these groups could cooperate with networks of occupational health specialists to design and implement strategies based on the findings of these reports. Systems for notification of infections with multi-resistant organisms could help in assessing the magnitude of the problem and issue warnings. The experts agreed that a wider approach, including at policy level, is needed to tackle this issue, one that is of particular relevance in a variety of sectors, from pig farming to home care.

Involving a broader range of stakeholders, consumers, patients and clients

Involving a wider range of stakeholders (e.g. suppliers of machines, equipment and PPE, food and hygiene inspectors, insurance companies, sectoral social partners) could help in designing more efficient prevention programmes, avoiding risks at the design stage and tailoring policies to the target group. For instance, the development of the safe needle systems should be discussed with providers. Pressure from clients in the food chain may also shape the attitude of farmers to using antibiotics in animal breeding.

One of the requirements for the development and implementation of an effective prevention strategy is available funding opportunities for all stakeholders involved. In addition to the provision of funding for prevention, other funding schemes (e.g. funds for regional development or sectoral funding) could be set up so that they are dependent on the implementation of good OSH. This was proposed, for example, for the farming sector: subsidies in this sector could be dependent on production and quality as well as on good worker protection.

Thought could be given to who could be involved as an intermediary or in the prevention approach to achieve better implementation while dealing with potential failures of the prevention approach. For example, more awareness could be raised among GPs by conducting, for instance, an information campaign to strengthen their knowledge of workplace risks due to biological agents.

Seeking synergy with public health measures

Some of the policies identified in this review are related to public health and measures under public health provisions, or medical care. For example, antibiotic resistance is one of the issues that have been discussed above. A large amount of the data on the effects of exposure to infectious microorganisms is obtained after outbreaks of diseases; the main focus of such events is public health and the prevention of pandemics, and workers' health may therefore be overlooked. Equally, there are diseases that are subject to obligatory reporting obligations under public health provisions, such as tuberculosis, and the

proposal of some experts was to extend such reporting obligations to other diseases and to learn from these examples when setting up monitoring systems. One issue addressed was the use of sentinels who report such diseases or health issues to a centralised system that validates and disseminates validated information or alerts to raise awareness of newly occurring or previously unaddressed diseases or health problems.

It has already been mentioned that there is currently no system in place in Europe that can respond quickly to emerging risks from biological agents; such a system could build on the epidemic alert systems in place in public health systems, and cooperation between the two policy areas would be beneficial. The latest COVID-19 epidemic and the previous epidemics of MERS and SARS are examples of situations in which cooperation between public health and occupational health stakeholders was essential to prevent risks to workers. The lack of protective equipment observed in these epidemics, along with the lack of a preventive approach to workers' health that relies on measures other than personal protective measures, has caused a dramatic situation in the provision of health care, illustrating the need for OSH measures, and the potential impact on public health measures and the provision of services in general if proper prevention is not implemented. In addition, experts pointed out that healthcare workers in outpatient medical care are the first to be exposed to possible outbreaks because they treat infected patients, and should therefore be included in preventive measures and receive training and information on how to deal with the risks.

Reporting mechanisms also exist for a number of serious diseases, such as tuberculosis, and for certain zoonoses, as mentioned above. France's experience with the observatory of zoonoses in agriculture could be shared across countries and policies and could provide valuable information to other initiatives in other Member States, such as the Finnish FOHS.

The Finnish experts, however, indicated, in relation to health care, the challenge of notifying authorities and public health institutions in time regarding exposures or (suspected) occupational diseases, which may be considerably delayed. The experts agreed that diseases classified as generally dangerous should be reported immediately. Three factors hindering adequate reporting were indicated, namely (1) the fact that different institutions need to be notified, yet one notification should be sufficient; (2) quick reporting is hindered by both healthcare privacy requirements and the data protection law in Finland; and (3) not every person who is ill as a consequence of exposure to biological agents reports their illness. The experts mentioned the additional significant barrier of a patient being able to withhold permission to inform their employer of any health problems. All these issues should be resolved to implement successful reporting schemes.

4.2 Vulnerable groups

The review also set out to identify groups of workers that are particularly vulnerable to exposure to biological agents because of their physical vulnerability or because they are less knowledgeable or have less training. Socially vulnerable workers are included in these considerations.

Vulnerable groups identified in all sectors were trainees and workers in their first jobs. Owing to a lack of experience and knowledge, they are more likely to be exposed to biological agents and are consequently at a higher risk of developing health effects due to this exposure. The bodies of young workers may also still be developing, and they may therefore have special vulnerabilities. Nurses in training and young healthcare workers, for example, were reported to be a vulnerable group for hepatitis B infections and measles in countries with low vaccine coverage.

Sector-specific vulnerable groups were also identified; for example, pregnant workers are a vulnerable group, especially in health care. The risk assessment duties included in the pregnant workers' directive need to be recalled, as they include biological agents, and some microorganisms may damage the unborn child. As already mentioned, in both waste treatment and animal-related occupations, the groups most vulnerable to organic dust were identified: pregnant women, people with pre-existing diseases and conditions, such as lung diseases, allergies and asthma, or diabetes (because of the increased risk of infection), and people with (other) chronic diseases. Furthermore, prison workers/guards are a high-risk

group regarding the spread of infectious diseases such as tuberculosis and measles. Regardless of control systems, outbreaks still occasionally occur in this group of workers.

Experts active in the waste treatment sector considered that the many temporary workers in this sector are more vulnerable, because they tend to be less informed, may be overlooked in training, may have less access to OSH services and may lack the appropriate vaccinations. Migrant workers may have communication problems (e.g. a worker's instructions may be presented in a different language from the worker's native language). Furthermore, consulting workers and training people who have difficulties understanding the local language, especially in low-skilled jobs, is considered a problem, as are the conditions under which temporary workers are subcontracted, as it is unclear who is responsible for preventive and hygiene measures (for instance receiving the necessary vaccinations), and these workers may therefore fall in between, as coordination is not ensured by service providers. The topic of migrants and refugees is currently being discussed at both national level and EU level. For instance, the European Agency for Law Enforcement Cooperation (Europol) is addressing the protection of border staff and staff who deal with securing borders and carry out controls against infectious diseases that they may encounter when they are in contact with migrants and refugees. New or re-emerging microorganisms may also have been introduced because of the increase in migration, travelling and transport, and may put some groups of vulnerable workers at risk.

In addition, outdoor workers might be at higher risk because of climate change and the spread of biological agents that are not endemic in their geographical area, as well as unforeseeable conditions; examples are the spread of tick-borne diseases such as Crimean-Congo haemorrhagic fever or the spread of leptospirosis transmitted by rodents. This may also increase the risk to vulnerable outdoor workers. Specific risks to vulnerable workers, such as young people engaged in help schemes or apprentices in some outdoor professions, would have to be considered.

Cleaning (in the healthcare sector and the waste treatment sector) and maintenance work (in the waste treatment sector) were also considered to be jobs at risk. This was confirmed in several sectors, for example health care. Workers who work at clients' premises may also be at risk, as the implementation of measures may be difficult. One issue that was mentioned is needlestick injuries, but there may be many other risks for which measures have not been taken. One related sector that was mentioned was home care.

One particular group that also emerged from the discussions and was discussed by the experts, workplace practitioners and stakeholders in the stakeholder workshop was people with chronic diseases and immunocompromised individuals. There was no agreement on whether or not immunosuppressed individuals should be regarded as a vulnerable group, but immunocompromised people were seen as a vulnerable group. The relationship between stress factors and exposure to biological agents was investigated in Germany. Acute stress may lead to mistakes, consequently increasing the risk of accidents, for example needlestick injuries in health care, as mentioned earlier. Long-term stress may also increase individual susceptibility through effects on the immune system (immunosuppression and immunomodulation), which may affect an individual's defences against infections, sensitisation or toxic effects. These considerations are now included in TRBA 400, 'Guideline for risk assessment and for the instruction of employees regarding activities involving biological agents', which has a dedicated chapter on psychological stressors when working with biological agents. The guideline sets out that these should be taken into account when carrying out a workplace risk assessment in workplaces with potential exposure to biological agents.

4.2.1 Recommendations

Since many groups of workers were identified as vulnerable to risks due to biological agents, the development and/or implementation of preventive measures to control risks due to biological agents in the workplace should specifically take these workers into account and also consider them when performing risk inventories and evaluations. As an example of how vulnerable workers can be included when developing preventive measures, the Finnish Best Practice Sharp Instruments in Healthcare Project includes new regulation and combined biological exposures and sharp instruments. An element of the project is a video tutorial that is constantly on display, through which information also reaches temporary workers.

As the recent coronavirus crisis demonstrated, risk assessment may also have to focus on the biological agents in question, identifying those workers who might be at higher risk and the specific tasks under which vulnerable workers may be at risk. People with pre-existing diseases and conditions, and especially those with respiratory disorders, were recognised as being particularly vulnerable to the coronavirus, for example. Preventive measures may need to be tailored to include groups that may be especially vulnerable to specific biological agents, and considerations regarding vulnerable groups should be included in any workplace risk assessment and even more so in circumstances in which contingency plans are set up. In some circumstances, such as those of maintenance workers or cleaners and temporary workers, the working environment may be changing, and this should also be considered. Circumstances for outdoor workers may be equally challenging, and, lastly, workers who are working at clients' premises may also be at risk.

4.3 Monitoring systems

In this review, one of the objectives was to identify monitoring systems that record diseases linked to exposure to biological agents. The aim was to identify the diseases and exposures that are recorded, assess whether or not these systems feed into workplace prevention and identify any gaps in methodology or information that need to be filled. A number of systems were first identified, based on the stakeholder survey, and analysed. The conclusions from this analysis as well as the conclusions based on the information provided from the literature survey and the experts' assessment as a result of the qualitative research are presented in this chapter. It presents conclusions on the links between the information provided by these systems and issues in workplaces, as well as recommendations for the development of the systems and how they could link to and feed into better prevention in workplaces.

4.3.1 Monitoring systems for diseases

The evaluated European systems used to monitor occupational diseases vary. They differ with respect to which diseases are registered, the type of information that is registered and the level of detail, who performs the registration, and the coverage in terms of industrial sectors and worker groups. Some groups (e.g. those who travel for work) or specific exposures may not be covered by most of the systems. These differences make it difficult or even impossible to analyse the diseases due to biological agents at, for instance, European level, and hinder cooperation and/or knowledge exchange.

The literature review (EU-OSHA, 2019a) provides an overview of those diseases that can be recognised in the Member States as occupational diseases. Generally, some of the priorities that the experts identified are reflected in the types of recognised diseases that are recorded by these systems. This is the case for, for example, farmers' lung and hypersensitivity pneumonitis. However, it is impossible to draw conclusions from those figures on the actual risk in workplaces, and the level of detail is very limited, since, as stated earlier, respiratory symptoms are more or less summarised under a very general heading.

4.3.2 Data gaps of monitoring systems for occupational diseases

Under-reporting

Under-reporting of occupational diseases by those who should register cases (e.g. occupational physicians, employers, workers) is considered a general issue and was identified as one of the weaknesses of most, if not all, of the monitoring systems that were evaluated. However, the exact level of under-reporting cannot be quantified, and thus, for now, the actual number of work-related diseases occurring in general, including diseases due to biological agents, is (much) higher than the number reported in the various countries and remains an educated guess at best. This is also the case for the sectors that have been identified as sectors/occupations of concern in the review, which include arable farming, animal breeding/caring/handling, waste management and health care. An important factor contributing to under-reporting may be under-recognition, caused by, for example, a general lack of knowledge and awareness of risks caused by biological agents. In systems based on reporting by (occupational) physicians, the degree of under-reporting is also affected by the level of physician participation. In systems based on compensation, under-reporting may also occur because the individual is unaware of the availability of compensation or does not meet its eligibility criteria. Providing more guidance and training may result in less under-reporting and thus a better overview of the occurrence of occupational diseases in Europe, including occupational diseases due to exposure to biological agents in the workplace.

Coverage of sectors and occupations

Self-employed workers are often not included in the registration process. Some systems report limited coverage of specific sectors of the workforce (e.g. agriculture) or specific groups of workers, such as maintenance workers, who may not be covered either by legislation or by notification and recognition procedures. In the chapter on vulnerable workers, a number of workers with potentially insufficient coverage were identified, for example temporary workers (for instance migrant workers in agriculture or waste management) and those who travel for work or are in contact with travellers or immigrants. There is uncertainty about whether or not diseases that these individuals contract during the course of their travelling or placements abroad are registered as work-related or occupational diseases. In addition, some countries highlighted specific groups of workers. Another group that was mentioned specifically is young workers or trainees, for instance when they engage in health systems abroad. More effort is needed to ensure the recognition of health problems affecting those groups, their work-relatedness and reporting of diseases to the monitoring systems, and awareness among those who report these diseases.

Guidance and training for registration of diseases

Most of the registration systems that were evaluated in this project are obligatory but fail to provide much guidance and training for the individuals that register the cases. For instance, (detailed) information on how to diagnose diseases due to biological agents is not always available. However, some of the evaluated systems do provide guidance regarding biological agents (in Denmark, Germany and the Netherlands, this is specifically stated). Providing the registrants with more guidance and training on this topic may result in less under-reporting and a better overview of the occurrence of occupational diseases in Europe, including occupational diseases due to exposure to biological agents in the workplace. Likewise, wider access to the background information available in these systems on exposures and conditions of exposure, as well as the potential causes of any health problems, would ensure that the systems can be adjusted and refined, and ongoing training and retraining can be provided to those who report cases. Such a feedback mechanism does exist for a number of alert systems that are described in this review, and the valuable contribution of these systems to the improvement of workplace monitoring should be more widely recognised. Depending on the networks providing the information —

whether they are occupational health centres, as in the French approach, or specialist networks, such as dermatologists and pulmonologists in the United Kingdom's THOR networks — the specialist knowledge could be a valuable asset to progress in the recognition of diseases at the international level.

Availability of data on diseases

The output of the monitoring systems is generally made available by means of annual reports and/or crude statistics, which are often publicly available. In general, the level of detail in these documents is not very high, and thus the information available on exposure to biological agents in the workplace and their associated health risks is not extensive. The specific data collected by the individual monitoring systems are often not publicly available, which makes it difficult for companies or branch organisations to take a closer look at the information that is relevant to their sector. Exceptions are data collected in the Dutch system and in the United Kingdom's THOR network. The latter also operates an ad hoc data enquiry service enabling interested parties to request information on cases of work-related ill health reported to THOR, an example that could be followed in other countries, even if it was restricted to occupational physicians or inspectors operating in specific sectors. Some systems also collect information on follow-up action in workplaces, and this information can be very valuable where similar problems occur, in research or for the development of workplace guidance.

Harmonisation of monitoring systems across Europe

It would be a great advantage if data from monitoring systems across Europe were structured and presented in a similar way and according to the minimum set of parameters already outlined in the literature review (EU-OSHA, 2019a), to enable a comparison of the systems between countries, to detect possible trends and to stimulate international cooperation. The differences between European monitoring systems (i.e. coding diseases and other factors in the registration process) and the lack of transparency in how these systems work make it very difficult to harmonise information provided by them. Harmonisation of the coding of important parameters regarding the registration of cases of work-related diseases and/or occupational diseases would benefit the surveillance of the health of the working population in Europe. The standardisation of these systems, including providing output in a common language, would therefore be considered a good step forward.

The minimum set of information parameters proposed earlier includes information on gender, age, occupation or industry and the circumstances of exposure. Such information could be structured around a harmonised thesaurus, such as the French TEO, that would provide information on biological agents and health issues. The literature review also provides recommendations on how to assess the usefulness of monitoring systems, and this includes considerations of how the information may be presented and used to serve prevention.

Use of data

The evaluation of the various systems for monitoring occupational diseases in Europe revealed that, in general, no direct link seems to exist between these monitoring systems and the development of prevention programmes.

The dissemination of the results of the registries to workplaces and labour safety authorities is essential for the effective use of this information for prevention. In some cases, the annual reports are at least actively shared with relevant stakeholders in the field of occupational disease prevention. However, the extent to which the systematically collected information is actually used to help target prevention remains unclear. Therefore, it is also unknown whether or not the information gathered on the basis of these monitoring systems with regard to biological agents in the workplace is actually used to prevent or at least better control these exposures, and to ensure that exposures are as low as possible and that workers are protected in the best way possible.

The way in which the information is actually used to target preventive measures does not seem to be structurally evaluated. In addition, since in general the level of detail in, for instance, the annual reports is not very high, and thus the available information on exposure to biological agents in the workplace and their associated health risks is not very extensive, it remains at least questionable whether or not this type of information is suitable and detailed enough for identifying and implementing the necessary preventive measures to deal with this type of exposure. Experts have highlighted the need to digest and

communicate such information in a way that makes it accessible to the workplace level and in a way that is suitable for the target groups. Such a function seems to be fulfilled by some of the expert networks that exist, for instance those that are linked to a reporting system (for instance for specific zoonoses) and those mentioned above that are linked to the alert and sentinel systems.

Linking monitoring systems for occupational diseases to public health systems

In addition to information that is gathered by means of monitoring systems for occupational diseases, information that is collected as part of the public health system could also be a valuable source of information, especially with regard to diseases for which the relationship with exposure in the work environment is not directly clear to a worker and/or an employer. Moreover, GPs are sometimes involved in the registration of occupational diseases and could also register cases of occupational diseases that are not picked up by occupational physicians and other OSH professionals involved. However, some information, for instance information on the work history of the person in question, would be needed to make information collected as part of the public health system useful for workplace purposes. It could be supplemented by information from job-exposure matrices, as proposed by some experts in the stakeholder workshop. Equally, information from such registries — whether obtained for the purpose of protecting animal health (in the case of zoonoses) or public health (in the case of certain infectious diseases, such as tuberculosis) — could be useful in recognising outbreaks of diseases and organising timely workplace prevention in the sectors concerned. The precondition for this, however, would be an exchange mechanism with occupational health authorities or expert networks. Some of the systems mentioned by the stakeholders in the questionnaire survey ensure this exchange, and some are traditionally established at both workplace level and public health level. For other systems, such a link would still need to be established. Success factors could be shared more on a European level, in coordination with the ECDC.

4.3.3 Monitoring systems for exposures

Little information is available on exposure to biological agents in the workplace. These exposures are not measured frequently, and only a few systems for monitoring them exist. The quantification of exposure to biological agents is known to be complex.

The following issues should be taken into account when measuring exposure to biological agents:

- Fluctuation in exposure: biological agents often relate to living organisms. Because they can grow themselves, multiply and die, exposure to biological agents varies more over time than exposure to chemical agents. A single exposure measurement is only a snapshot of the concentration of biological agents in the air. Thus, to obtain an accurate picture of the exposure, repeated measurements are needed. In addition, exposure concentration is highly dependent on the season and the place in which it is measured. This complicates the generation of a representative picture of exposure via the air.
- The different routes of exposure (inhalation, oral and skin exposure).
- The availability of measurement methods: only a few standardised methods for biological agents are described. Both viable and non-viable methods are available, and often, for the measurement of exposure to specific microorganisms in the air, no specific methods are (yet) available.

The challenges of the measurement of biological agents were explained in detail in the literature review (EU-OSHA, 2019a).

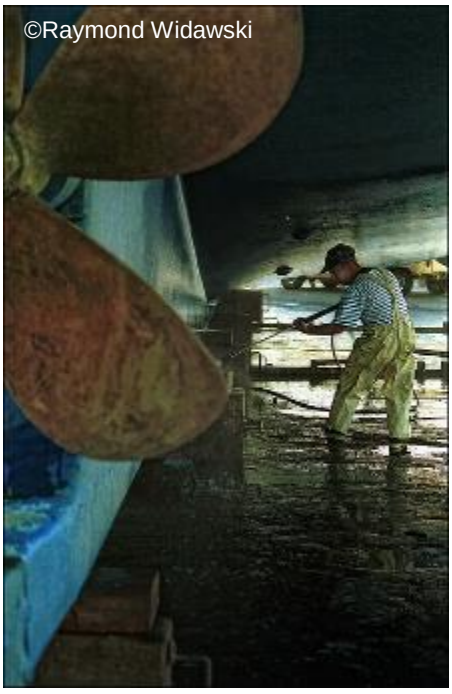
To improve the understanding of exposure to biological agents at work and to enable the control or prevention of such exposures, the experts considered it essential that the measurement techniques and analytical methods concerning biological agents be improved. In addition, as the occurrence of respiratory (allergenic) diseases and the occurrence of skin diseases are also important triggers for the performance of workplace measurements of chemical substances, it would be beneficial to design measurement strategies that cover both biological and chemical substances, to provide data on exposure to both types of substances in specific occupations and sectors if possible. So far, setting reference values or exposure limits has been based on experiences from the chemical substances area.

However, there are differences and challenges in determining biological agents (living organisms that are growing).

One of the conclusions of the literature review was that exposure measurement methods should be developed for those diseases that are most frequently recorded and that measurement for agents causing respiratory and skin diseases and important sectors identified in the review should be prioritised. Some of the exposure studies conducted by national institutions provide valuable information on exposure to biological agents in, for instance, livestock workers and waste management workers, and the textile industry (on endotoxins).

With regard to monitoring exposure, the categorisation and classification of these agents is also an important issue. The current classification of biological agents in Directive 2000/54/EC focuses on living microorganisms. In many sectors, workers are potentially exposed to a variety of biological agents. Owing to this classification and a link to certain containment measures depending on classification, a thorough risk assessment for all biological agents present in a certain workplace may be perceived as requiring a study of each individual biological agent, which is currently not possible for all biological agents, as the data for some are simply unavailable. The lack of good quantitative data on the exposure and associated health effects (exposure-effect relationship) in turn is an obstacle to the derivation of OELs, which is a major barrier to evaluations based on quantifiable results.

The directive's definition of biological agents means that substances or structures that originate from living or dead organisms (such as exotoxins, endotoxins, glucans, mycotoxins and allergens) seem to fall outside its legislative purview. This may have implications for how well these biological substances are considered in the national monitoring systems and health policies of Member States. The precise impact of this on official reporting of illnesses and diseases related to such types of biological agents is unknown. For instance, several forms of hypersensitivity pneumonitis caused by exposure to allergens of biological origin are registered in the occupational disease monitoring systems evaluated in this study. Although these substances may pose substantial health risks, demonstrated by the fact that these diseases are registered in several countries, with regard to registration, control and prevention, these substances may fall in between the regulations for chemical and biological agents, and may thus be either structurally under-reported and/or not managed appropriately.



During the focus group sessions, many intermediaries focused more frequently on biological risks in terms of high-risk activities or high-risk processes within a sector (such as accidents with needles, problems with specific processes in waste treatment, e.g. collection and sorting) and less frequently on the perspective of a certain biological agent and/or a certain health effect. For instance, an intermediary

active in a waste treatment plant indicated that they generally describe their exposure to biological agents as a complex mixture of all kinds of biological agents (often indicated as organic dust), without trying to identify specific agents, and also focus their control strategy on biological agents as a whole. In addition, the evaluation of available exposure databases showed that, where exposure to biological agents is being monitored and registered, this mainly consists of exposure data for general markers (for instance endotoxin exposure in the MEGA database), while more specific exposure data are less available. It was suggested that exposure to mixtures (moulds, organic dust and dust in waste management, as well as aerosols in wastewater treatment) should be better reflected in the Biological Agents Directive and general markers of exposure to biological agents should be considered (such as organic dust or bioaerosols, or endotoxins, as a marker for Gram-negative bacteria; peptidoglycan or muramic acid as a marker of Gram-positive bacteria; glucans as a marker of fungi/moulds; and extracellular polysaccharide antigens of the *Aspergillus* and *Penicillium* species — EPS-Pen/Asp — as a more specific marker of fungal exposure). In combination with standardised measurement methods, which are assumed to be more feasible to develop for general markers of exposure than for specific biological agents, this would stimulate exposure assessment, surveillance studies and epidemiological studies. This in turn would improve our general knowledge with regard to occupational risks related to biological agents and may lead to the derivation of OELs for biological agents, which is expected to stimulate control of these exposures in the workplace. It was also mentioned that quantifying exposure to biological agents is very expensive, and therefore a qualitative approach to exposure should be encouraged as a first step.

FIOH has developed FINJEM. Even when only a job title is known, the exposure of a worker can be estimated based on the exposures measured in large groups of workers with similar job titles that have been logged in the database over a long period. The exposures that are relevant to biological hazards in the FINJEM database are those to organic dust (e.g. animals, flour, plants, softwood and hardwood dust) and to microbiological agents (e.g. mould spores and Gram-negative bacteria of non-human origin). Other job-exposure matrices could be built on this model.

4.4 General considerations

Making the protection of workers from biological agents a priority

Most of the experts and workplace practitioners indicated that biological agents are often not considered an OSH priority at the national level, which has resulted in a reactive rather than a proactive approach, compared with other dangerous substances in the workplace, and has limited resources for developmental projects, research, inspections and consultations. If biological agents were a higher priority on the national OSH policy agenda, more knowledge regarding this topic would be generated, which in turn would help employers to deal with this risk in the workplace more effectively. Many of the OSH experts mentioned support and financing for research and practical prevention and setting up the structures needed to ensure a structured and preventive approach and timely and targeted reaction to events that suddenly occur. Equally, resources and knowledge could be improved at the level of labour inspections and OSH services, to ensure implementation and OSH support at workplace level.

Raising awareness is key

As a general lack of awareness of the risks posed by biological agents was flagged by all the experts, raising awareness is an important priority. It is also an important means by which to ensure that the people involved consider this (potential) risk on an individual level. Groups for which more awareness was considered especially important were as follows:

- Occupational physicians, with regard to observing an increase in the incidence of known diseases in novel occupational settings. They also play an important role in health surveillance and the implementation of prevention measures, and should have the necessary authority during interaction with management of, for instance, health establishments.
- GPs, with regard to the possible link between observed health effects and the (previous) work environment of a patient.
- New/young workers in relevant sectors/occupations, who need to be trained and informed before they start working. This is especially important considering that they have been

identified as a vulnerable group in many of the sectors mentioned above, especially as regards allergic effects, which may lead to not only early dropout from certain professions, with dramatic effects on their development, but also potentially high retraining costs and difficulty ensuring employment in another profession.

- Based on the findings outlined in this report, other groups that lack awareness of the risks are:
  - labour inspectors;
  - OSH services;
  - public health institutions;
  - employers;
  - workers.

For all these groups, the topic of biological health risks should preferably be part of their professional education, and targeted information and awareness campaigns could be organised to improve their knowledge and mobilise these groups to ensure better OSH prevention in this area.

Improving national visibility and access to experts

For a more structured policy on the prevention of the health risks associated with biological agents in the workplace, it is advisable to improve the national visibility and approachability of experts of specialised institutions, for example by means of telephone lines and the use of intermediaries such as specialised OSH consultants. The experts in the interviews, the workplace practitioners and those involved in the stakeholder consultation — at the beginning through the questionnaire survey and at the end in the stakeholder workshop — all remarked on this. In several countries, there are expert networks with knowledge of exposure to biological agents at work that have different focuses and different statuses. Overall, 26 respondents to the stakeholder survey from 14 countries reported that they were familiar with networks in their countries, and most provided a website link or additional information. The expert networks mentioned by the respondents to the questionnaire were mostly organisations of occupational physicians or hygienists, such as the British Occupational Hygiene Society of the United Kingdom and Denmark's conglomerate of occupational physicians employed at seven different hospital departments across the country but working under the Scientific Society for Occupational and Environmental Medicine.

Knowledge exchange

An exchange between the networks mentioned above, better visibility and a better link to policy and prevention could help advance prevention of workplace risks from exposure to biological agents. On the one hand, the recognition of health problems could be improved and, as in the RNV3P network in France, alerts could be issued to prevention actors when a new risk or a new disease is recognised. On the other hand, these issues could be brought to the attention of policy-makers and those who develop standards, to ensure that they are addressed in regulations, guidance and the control of implementation by, for example, labour inspectors.

Another way to facilitate knowledge exchange is by organising a network at national or European level, along the lines of the French RNV3P, in which occupational health professionals at occupational disease centres and OSH services work together as a network of experts (universities, practitioners and institutional experts sharing information via working groups, comitology and other forms of information exchange). Another example is ABAS in Germany. Although many of the expert groups mentioned were not directed towards a specific sector and/or agent/disease, this is most frequently the case in the healthcare sector. It would be beneficial if such a network targeted a specific issue; for example, one group of experts, as mentioned earlier, focused specifically on MRSA on pig farms, where this biological agent is of utmost concern. However, knowledge exchange across country borders is also considered necessary, especially regarding effectively dealing with new risks and factors that increase the risk of epidemics**.**

The development of an effective information exchange strategy on policy measures and the lessons learned between countries is recommended, one which preferably includes a European (or even global) system designed to respond to emerging risks quickly and in a more structured manner. Although the experts pointed out several knowledge gaps in the field of occupational risks of exposure to biological agents, for which they recommended additional research (e.g. on the occurrence of biological agents, causality between exposure and developing adverse health effects, and the establishment of limit values), many interesting examples of practical measures were shared. These examples were often bound to a specific profession, company, sector or country, and often more or less tailor-made for a specific situation and/or set of circumstances; as a result of this, they were often not applicable in a broader way (apart from differences in regulations, the transferability of such measures in one occupation from one country to another country may even be more realistic than from one occupation to another occupation in the same country). The prevention of risks from biological agents should be better integrated into an overall prevention approach, based for example on some experiences from the management of chemical agents (and some of the agents addressed here are chemicals).

Much can be gained from improving the transfer of information and from best practices in this field. Therefore, as well as filling in the gaps by conducting additional research, it is recommended to explore how existing data, knowledge, experiences and best practices on preventive measures to protect workers against occupational risks of exposure to biological agents in different sectors can be collected and better shared so that they reach and benefit policy-makers and workers in practice. When national initiatives are presented to EU-OSHA, it can facilitate the sharing of good practice examples on the EU level, for example by publishing an article on its OSHwiki platform.

Transfer of research knowledge to the workplace level

The experts involved in this review stressed several times the need to transfer research knowledge to workplaces to ensure better prevention. The expert networks could act as intermediaries in this method of communication, provided that they include a range of expertise and have access to the knowledge of what is happening in workplaces. Cooperation between expert networks and research institutions across countries would help ensure the best use of resources and a rapid exchange of information, would help validate case reports of emerging issues, and would shorten the process between the recognition of an issue and its prevention at the workplace level.

The institutes could facilitate the influencing of the agenda-setting process, as well as the improvement of the availability of robust evidence in policy development and evaluation. Other factors contributing to the visibility of concerns regarding biological agents at work for key decision-makers at a national level are lobbying groups focusing attention on the problem, intensive or repeated media attention and public awareness. In addition, a proper dialogue and better collaboration between relevant stakeholders at several levels are required for shaping policy agendas and influencing policy formation and change.

More funding for systematic research needed

In addition to the points above, the experts also highlighted that there are few funding schemes for research available, as identified in this research. There were several proposals for systematic research made by the OSH experts, for example epidemiological studies, development of measurement methods and research into efficient detection methods and prevention strategies at the workplace level. Some countries did report on specific research initiatives, concerning either the identification of biological agents or the measurement of specific indicators such as endotoxins in workplaces, or measurement campaigns. An interesting example was reported from Finland, where continuous research did support the development and continuous improvement of the occupational health service for the farming sector, quite a unique initiative in Europe. However, the OSH experts highlighted the lack of financing for such systematic research, while recognising the urgent need for a systematic approach to fill the many knowledge gaps identified in this review. It was also mentioned that research could build on the experiences of some countries with more developed research programmes and experience gathered in the area of hazardous chemicals. An exchange of research between organisations, to ensure that knowledge is mapped and that the topics to explore are prioritised, would be important to pursue.

Involvement of sectoral organisations

The workplace practitioners involved in the focus groups stressed the need to act at the sectoral level and increase awareness among employers and workers in the sectors covered by this research. Cooperation with sectoral organisations could support the transfer of knowledge and guidance to the workplace level and help identify areas of concern, for example when conditions are changing in the sector. Several issues, such as the increase in multi-resistant microorganisms, the industrialisation of agriculture and environmental regulations that have an impact on waste management cycles, could be brought to the attention of policy-makers and workplace practitioners at an earlier stage. Another suggestion from OSH experts was that the sectoral organisations could investigate specific issues, such as asthma in specific occupations, to support research and prevention, or support such research actively by addressing their members and supporting data collection.

Cross-sector collaboration on these issues, for example regarding antibiotic resistance, could also be enhanced. An example proposed in this review is the collaboration between veterinarians, the agriculture sector, public health, the food industry and the healthcare sector regarding the issue of antibiotic resistance to ensure a lifecycle approach. It was also proposed that clients, patients and consumers be involved in these strategic approaches, to ensure a sustainable approach at all levels that would avoid the development and spread of multi-resistance to antibiotics. This would ensure information flow, awareness-raising at all levels and advocacy for a sustainable approach.

EU directive

The experts involved in this review agreed that the EU directive on the protection of workers from biological agents at work provided an important framework that reflected the general prevention principles of the Framework Directive. However, they raised a few important points that may be considered when revising the directive or designing guidance for its implementation.

The main focus of the directive is currently on microorganisms in relation to infectious diseases, whereas the 'biological agents' concept applied in some Member States is broader. How the directive and the overall OSH legislative framework could address the increasing importance of allergens should be considered. Some experts recommended that the directive cover a wider definition of biological agents: in addition to living (micro)organisms (such as bacteria, viruses, fungi, yeasts and prions), substances or structures that originate from living or dead organisms (such as exotoxins, endotoxins, glucans and mycotoxins), allergens (originating from living or dead organisms, plants or animals) and carriers of a variety of biological agents (e.g. organic dust and bioaerosols) that contribute greatly to exposure to biological agents in work environments. It should therefore be ensured that there is no gap in the prevention of OSH risks between the chemical and biological agent-driven risks and that the legislative areas are complementary and cover all risks. This would allow the inclusion of toxic and allergenic or irritative effects related to these substances, notably in sectors in which the level of awareness of these issues is low and prevention may be difficult to implement. Some of these sectors have been reflected on in this review, for example the agricultural sector, which is characterised by a wide range of tasks and procedures that may involve risks.

Moreover, the definition of biological agents differs between countries; countries may add specific biological agents to the list of agents in the directive. Some Member States, such as Germany, provide a list of biological agents in Risk Group 1. An exchange of national information at the European level would facilitate the creation of an international list of biological agents or a regular update at the European level through technical amendments. Furthermore, because of the more dynamic society in which we operate today, a more continuous appraisal of issues/the state of the art with regard to biological agents instead of a review of a directive once every 10-15 years may be necessary. The participants of the stakeholder workshop recommended updating the list of biological agents (Annex III

to the directive) more regularly (for instance every 6 months). In addition, the annexes to the directive could include relevant agents and activities, especially for Risk Group 1.

It was also recommended that the annexes to the directive be made context specific for jobs and sectors, and address vulnerable groups. One of the main focuses of the directive is on the sectors in which working with biological agents is part of the primary process (industrial processes, laboratories and animal rooms) or in which workers come into contact with human or animal patients (healthcare and veterinary care facilities), on which specific articles focus (Articles 15 and 16) and for which indications concerning containment measures and containment levels (Annex V) and containment for industrial processes (Annex VI) are specified. It should be noted that, probably at least partly due to this directive, these sectors are known for their high level of regulation, control and preventive measures, and in general the workers active in these sectors are trained and assumed to be relatively well aware of the risks they are potentially exposed to. The containment measures set out in these annexes could at least be partially implemented in other sectors, but in many sectors in which exposure to biological agents is not part of the primary process or part of a stringent control/prevention strategy, but still an inherent part of everyday working practice, these containment measures are not easy to put into place. The finding that a wider range of occupations is considered 'at risk' should be reflected in the directive, to ensure that these occupations are also included in the development and implementation of preventive measures in the relevant sectors. Such occupations include those in which exposure to biological agents is mainly unintended, such as occupations in composting, recycling, agriculture (animal and arable farming), food processing, home/outpatient care and education, and occupations such as cleaning and maintenance work. Including a reference to vulnerable groups could be considered, as they may vary depending on the sector and the biological agent. In the recent coronavirus epidemic, for instance, workers with respiratory disease or asthma and other workers with chronic health problems were identified as being at particular risk. These aspects may differ depending on the group considered, and, in the specific case of biological agents, issues such as immune status may also play a role.

An approach that focuses on high-risk activities or processes within a sector, instead of a biological agent-based approach, may be more effective for the development and implementation of preventive measures. In addition, as already mentioned, the directive could take into account the context of sectors, jobs, vulnerable groups, etc., much more, so that employers can better interpret and implement it in practice. Furthermore, some sectors that are highly affected by biological exposure, such as the agricultural sector, have a high number of SMEs, and the working conditions are changing because of

restructuring and increasing industrialisation. They are also an audience that is difficult to reach, and they have a high proportion of temporary workers and migrant workers who may be particularly vulnerable. An example of development at a practical level is the TRBA in Germany. The implementation of legislation would be improved by the creation of practical guidance for employers, in plain language, on how to read and use the provisions of the directive. A good example of a directive that includes practical guidelines on implementation is the EU directive on electromagnetic fields.

Guidance for labour inspectors would also help support the implementation of the directive, as this may be quite challenging in sectors with unintended exposures. Some of these are fast-growing sectors, such as waste management and home care, and, at the same time, control and inspection may be a challenging task in these sectors. An exchange between those who implement the regulations in practice and an exchange with OSH services could be beneficial in identifying those aspects that are particularly challenging and agreeing on areas in which support is needed.

5 References

ABAS/BauA, 2005. Bericht "Irritativ-toxische Wirkungen von luftgetragenen biologischen Arbeitsstoffen am Beispiel der Endotoxine". Retrieved June 2020 from https://www.baua.de/DE/Aufgaben/Geschaeftsfuehrung-von-Ausschuessen/ABAS/pdf/Endotoxinpapier.html

ABAS/BauA, 2007. The importance of mycotoxins in the context of workplace-related risk assessment (Sachstandsbericht - Bedeutung von Mykotoxinen im Rahmen der arbeitsplatzbezogenen Gefährdungsbeurteilung). Retrieved June 2020 from https://www.baua.de/DE/Aufgaben/Geschaeftsfuehrung-von-Ausschuessen/ABAS/pdf/Bedeutung-von-Mykotoxinen.html.

ABAS/BAuA, 2008. Respiratory sensitising agents (Technische Regeln für biologische Arbeitsstoffe und Gefahrstoffe (TRBA/TRGS 406) — Sensibilisierende Stoffe für die Atemwege). GMBl. 2008 Nr. 40/41, 845-855. Retrieved April 2020 from: https://www.baua.de/DE/Angebote/Rechtstexte-und-Technische-Regeln/Regelwerk/TRGS/TRGS-TRBA-406.html

ABAS/BAuA, 2010a. Safety and health for activities involving biological agents in sewage plants (Technische Regel für Biologische Arbeitsstoffe (TRBA 220) — Sicherheit und Gesundheit bei Tätigkeiten mit biologischen Arbeitsstoffen in abwassertechnischen Anlagen). GMBl. 2010 Nr. 68-80, 1405-1416. Retrieved February 2020 from: https://www.baua.de/EN/Service/Legislative-texts-and-technical-rules/Rules/TRBA/TRBA-220.html

ABAS/BAuA, 2010b. Protective measures for activities involving microbially contaminated archival materials (Technische Regel für Biologische Arbeitsstoffe (TRBA 240) — Schutzmaßnahmen bei Tätigkeiten mit mikrobiell kontaminiertem Archivgut). GMBl. 2010 Nr. 68-80, 1417-1427. Änderung: GMBl. 2015 Nr. 29, 566-576. Retrieved February 2020 from: https://www.baua.de/EN/Service/Legislative-texts-and-technical-rules/Rules/TRBA/TRBA-240.html

ABAS/BAuA, 2012. Classification of viruses into risk groups (Technische Regel für Biologische Arbeitsstoffe 462 (TRBA 462) — Einstufung von Viren in Risikogruppen). GMBl. 2012 Nr. 15-20 vom 25. April 2012, p. 299-372. 6. Änderung: GMBl. 2020 Nr. 14, 28. Retrieved April 2020 from: https://www.baua.de/DE/Angebote/Rechtstexte-und-Technische-Regeln/Regelwerk/TRBA/TRBA-462.html

ABAS/BAuA, 2013a. Protective measures for activities involving biological agents in laboratories (Technische Regel für Biologische Arbeitsstoffe 100 (TRBA 100) — Schutzmaßnahmen für Tätigkeiten mit biologischen Arbeitsstoffen in Laboratorien). GMBl. 2013 Nr. 51/52, 1010-1042, 1. Änderung: GMBl. 2014 Nr. 38, 814, 2. Änderung: GMBl. 2016 Nr. 42, 839, 3. Änderung: GMBl. 2017 Nr. 10-11, 205, 4. Änderung: GMBl. 2018 Nr. 15, 263. Retrieved February 2020 from: https://www.baua.de/EN/Service/Legislative-texts-and-technical-rules/Rules/TRBA/TRBA-100.html

ABAS/BAuA, 2013b. Classification of parasites into risk groups (Technische Regel für Biologische Arbeitsstoffe 464 (TRBA 464) — Einstufung von Parasiten in Risikogruppen). GMBl. 2013 Nr. 31, 594-619. Retrieved April 2020 from: https://www.baua.de/DE/Angebote/Rechtstexte-und-Technische-Regeln/Regelwerk/TRBA/TRBA-464.html

ABAS/BAuA, 2014, Biological agents in health care and welfare facilities (Technische Regel für Biologische Arbeitsstoffe (TRBA 250) — Biologische Arbeitsstoffe im Gesundheitswesen und in der Wohlfahrtspflege). GMBl. 2014 Nr. 10/11 S. 206, 1. Änderung: GMBl. 2014 Nr. 25, S. 535, 2. Änderung: GMBl. 2015 Nr. 29, S. 577, 3. Änderung: GMBl. 2016 Nr. 42, S. 838, 4. Änderung: GMBl. 2018 Nr. 15, 259. Retrieved April 2020 from: https://www.baua.de/EN/Service/Legislative-texts-and-technical-rules/Rules/TRBA/TRBA-250.html

ABAS/BAuA, 2015. Classification of prokaryotes (bacteria and archaea) into risk groups (Technische Regel für Biologische Arbeitsstoffe (TRBA 466) — Einstufung von Prokaryonten (Bacteria und Archaea) in Risikogruppen). Edition: August 2015. GMBl. 2015 Nr. 46-50, 910, 5. Änderung: GMBl. 2020 Nr. 14, S. 28. Retrieved April 2020 from: https://www.baua.de/DE/Angebote/Rechtstexte-und-Technische-Regeln/Regelwerk/TRBA/TRBA-466.html

ABAS/BAuA, 2016a. Criteria for the classification of biological agents (Technische Regel für Biologische Arbeitsstoffe 450 (TRBA 450) — Einstufungskriterien für Biologische Arbeitsstoffe), Edition: June 2016. GMBl. 2016, No. 23, 445. Retrieved April 2020 from: https://www.baua.de/EN/Service/Legislative-texts-and-technical-rules/Rules/TRBA/TRBA-450.html

ABAS/BAuA, 2016b. Classification of fungi into risk groups (Technische Regel für Biologische Arbeitsstoffe 460 (TRBA 460) — Einstufung von Pilzen in Risikogruppen). Edition: July 2016. GMBl. 2016 Nr. 29/30, S. 5623. Änderung: GMBl. 2020 Nr. 14, 284. Retrieved April 2020 from: https://www.baua.de/DE/Angebote/Rechtstexte-und-Technische-Regeln/Regelwerk/TRBA/TRBA-460.html

ABAS/BAuA, 2017. Guideline for risk assessment and for the instruction of employees regarding activities involving biological agents (Technische Regel für Biologische Arbeitsstoffe 400 (TRBA 400) — Handlungsanleitung zur Gefährdungsbeurteilung und für die Unterrichtung der Beschäftigten bei Tätigkeiten mit biologischen Arbeitsstoffen). Edition March 2017. GMBl. 2017 Nr. 10-11, 158-182. 1. Änderung: GMBl. 2018 Nr. 30, 589. Retrieved April 2020 from: https://www.baua.de/EN/Service/Legislative-texts-and-technical-rules/Rules/TRBA/TRBA-400.html

ABAS/BAuA, 2018. Safety and health for activities involving biological agents in waste treatment plants (Technische Regel für Biologische Arbeitsstoffe 214 (TRBA 214) — Abfallbehandlungsanlagen). Edition July 2018. GMBl. 2018 Nr. 30, 574. Retrieved March 2020 from: https://www.baua.de/DE/Angebote/Rechtstexte-und-Technische-Regeln/Regelwerk/TRBA/TRBA-214.html

Alonso, V.A., Pereyra, C.M., Keller, L.A., Dalcero, A.M., Rosa, C.A., Chiacchiera, S.M., Cavaglieri, L.R., 2013. Fungi and mycotoxins in silage: An overview. J. Appl. Microbiol. 115, 637-643. doi:10.1111/jam.12178

Alter, M.J., 2007. Epidemiology of hepatitis C virus infection. World J. Gastroenterol. 13, 2436-2441. doi:10.1016/S2255-4823(11)70024-8

Applebaum, K.M., Graham, J., Gray, G.M., LaPuma, P., McCormick, S.A, Northcross, A., Perry, M.J., 2016. An overview of occupational risks from climate change. Curr. Environ. Heal. Reports. 3, 13-22. doi:10.1007/s40572-016-0081-4

Anzivino-Viricel, L., Falette, N., Carretier, J., Montestrucq, L., Guye, O., Philip, T., Fervers, B., 2012. Domestic waste management: State of current knowledge and health effects assessment in general and occupational populations (Gestion des déchets ménagers et assimilés: bilan des connaissances et évaluation des effets sanitaires en population générale et au travail). Environ. Risque Sante. 11, 360-77. doi:10.1684/ers.2012.0559

Barber, C.M., Burton, C.M., Scaife, H., Crook, B., Evans, G.S., 2012. Systematic review of respiratory case definitions in metalworking fluid outbreaks. Occup. Med. (Chic. Ill). 62, 337-342. doi:10.1093/occmed/kqs056

Barros, M.B.D.L., de Almeida Paes, R., Schubach, A.O., 2011. *Sporothrix schenckii* and sporotrichosis. Clin. Microbiol. Rev. 24, 633-654. doi:10.1128/CMR.00007-11

BAuA, 2016. Documents on the individual occupational diseases — leaflets (Dokumente zu den einzelnen Berufskrankheiten — Merkblätter). Retrieved June 2020 from: https://www.baua.de/DE/Angebote/Rechtstexte-und-Technische-Regeln/Berufskrankheiten/Merkblaetter.html

Blais Lecours, P., Veillette, M., Marsolais, D., Cormier, Y., Kirychuk, S., Duchaine, C., 2014. Archaea in bioaerosols in dairy farms, poultry houses and wastewater treatment plants and their role in lung inflammation. Quebec: Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST).

BMAS/BAuA, 2020. Safety and health at work — Reporting year 2018 — Report on accident prevention at work (Sicherheit und Gesundheit bei der Arbeit — Berichtsjahr 2018. Unfallverhütungsbericht Arbeit. 2. Auflage). Dortmund: Bundesanstalt für Arbeitsschutz und Arbeitsmedizin. Retrieved from: www.baua.de/suga. doi:10.21934/baua:bericht 20191115

Broughton, A., Verger, C., Goffin, E., 2010. Pets-related peritonitis in peritoneal dialysis: companion animals or Trojan horses? Semin. Dial. 23, 306-316

Burton, C.M., Crook, B., Scaife, H., Evans, G.S., Barber, C.M., 2012. Systematic review of respiratory outbreaks associated with exposure to water-based metalworking fluids. Ann. Occup. Hyg. 56, 374-388. doi:10.1093/annhyg/mer121

Cano-Jiménez, E., Acuña, A., Botana, M.I., Hermida, T., González, M.G., Leiro, V., Martín, I., Paredes, S., Sanjuán, P., 2016. Farmer' s lung disease. A review. Arch. Bronconeumol. 52, 321-328.

Chin, T.L., MacGowan, A.P., Jacobson, S.K., Donati, M., 2014. Viral infections in pregnancy: Advice for healthcare workers. J. Hosp. Infect. 87, 11-24. doi:10.1016/j.jhin.2013.12.011

CNAM/DRP, 2020. Claims statistics 2018 all CTN (National Technical Committees) and by CTN (Statistiques de sinistralité 2018 tous CTN (Comités Techniques Nationaux) et par CTN). Retrieved April 2020 from: http://www.risquesprofessionnels.ameli.fr/fileadmin/user_upload/document_PDF_a_telecharger/etudes_statistiques/MP_2018/AT-TR-MP%202018%20tous%20CTN%20et%20par%20CTN%20(*n*-2020-037).pdf

Darby, A., Fishwick, D., 2011. Other respiratory diseases review. Research report RR874. Buxton, Derbyshire: Health and Safety Executive (HSE).

DGUV, 2011. Information on the germ load of water-mixed cooling lubricants (Information Keimbelastung wassergemischter Kühlschmierstoffe). Deutsche Gesetzliche Unfallversicherung, report BGI/GUV-I 762. Berlin: DGUV.

DGUV, 2016a. Information on the germ load of water-mixed cooling lubricants (Information Keimbelastung wassergemischter Kühlschmierstoffe). Deutsche Gesetzliche Unfallversicherung, DGUV Information 209-051. Berlin: DGUV.

DGUV, 2016b. MEGA data publications. Retrieved September 2016 from:http://www.dguv.de/ifa/gestis/expositionsdatenbank-mega/expositionsdaten-aus-mega-inpublikationen/index-2.jsp

DGUV, 2017. GESTIS Biological Agents Database. Retrieved April 2019 from: http://www.dguv.de/ifa/gestis/gestis-biostoffdatenbank/index-2.jsp.

Dickel, H., Bruckner, T., Altmeyer, P., Künzlberger, B., 2014. Seafood allergy in cooks: A case series and review of the literature. J. Ger. Soc. Dermatology, 891-901.

Downes, J., Rauk, P.N., VanHeest, A.E., 2014. Occupational hazards for pregnant or lactating women in the orthopaedic operating room. J. Am. Acad. Orthop. Surg. 22, 326-332.

Doyle, M.E., Hartmann, F.A., Lee Wong, A.C., 2012. Methicillin-resistant staphylococci: Implications for our food supply? Anim. Heal. Res. Rev. 13, 157-180.

Duarte, S.C., Pena, A., Matos Lino, C., 2011. Human ochratoxin A biomarkers: From exposure to effect. Crit. Rev. Toxicol. 41, 187-212.

Dulon, M., Lisiak, B., Wendeler, D., Nienhaus, A., 2015. Occupational infectious diseases among healthcare workers in 2014 (Berufsbedingte Infektionskrankheiten bei Beschäftigten im Gesundheitsdienst 2014). Zbl. Arbeitsmed., Arbeitsschutz und Ergonomie 65, 210-216. Retrieved April 2020 from: https://doi.org/10.1007/s40664-015-0030-3

Dutkiewicz, J., Cisak, E., Sroka, J., Wojcik-Fatla, A., Zajac, V., 2011. Biological agents as occupational hazards: Selected issues. Ann. Agric. Environ. Med. 18, 286-293.

Dutkiewicz, J., MacKiewicz, B., Lemieszek, M.K., Golec, M., Milanowski, J., 2015. Pantoea agglomerans: A mysterious bacterium of evil and good. Part I. Deleterious effects: Dust-borne endotoxins and allergens — Focus on cotton dust. Ann. Agric. Environ. Med. 22, 576-588. doi:10.5604/12321966.1185757

Dutkiewicz, J., MacKiewicz, B., Lemieszek, M.K., Golec, M., Skórska, C., Góra-Florek, A. Milanowski, J., 2016. Pantoea agglomerans: A mysterious bacterium of evil and good. Part II. Deleterious effects: Dust-borne endotoxins and allergens — Focus on grain dust, other agricultural dusts and wood dust. Ann. Agric. Environ. Med. 23, 6-29i. doi:https://doi.org/10.5604/12321966.1196848

Eduard, W., 2006. The Nordic expert group for criteria documentation of health risks from chemicals: 139. Fungal Spores. Stockholm: Arbetslivsinstitutet. Retrieved April 2020 from: http://www.inchem.org/documents/kemi/kemi/ah2006_21.pdf

Eduard, W., 2009. Fungal spores: A critical review of the toxicological and epidemiological evidence as a basis for occupational exposure limit setting. Crit. Rev. Toxicol. 39, 799-864.

Eduard, W., Heederik, D., Duchaine, C., Green, B.J., 2012. Bioaerosol exposure assessment in the workplace: The past, present and recent advances. J. Environ. Monit. 14, 334-339.

EU-OSHA (European Agency for Safety and Health at Work), 2003. Factsheet 41: Biological agents. Retrieved April 2020 from: https://osha.europa.eu/en/publications/factsheet-41-biological-agents/view

EU-OSHA (European Agency for Safety and Health at Work), 2007. Expert forecast on emerging biological risks related to occupational safety and health. Luxembourg: Publications Office of the European Union.

EU-OSHA (European Agency for Safety and Health at Work), 2009a. Expert forecast on emerging chemical risks related to occupational safety and health. Luxembourg: Publications Office of the European Union.

EU-OSHA (European Agency for Safety and Health at Work), 2009b. Biological agents and pandemics: Review of the literature and national policies. Luxembourg: Publications Office of the European Union.

EU-OSHA (European Agency for Safety and Health at Work), 2011. Factsheet 100 — Legionella and legionnaires' disease: European policies and good practices. Retrieved May 2016 from: https://osha.europa.eu/en/tools-and-publications/publications/factsheets/100/view

EU-OSHA (European Agency for Safety and Health at Work), 2013. Green jobs and occupational safety and health: Foresight on new and emerging risks associated with new technologies by 2020 — Report. Luxembourg: Publications Office of the European Union.

EU-OSHA (European Agency for safety and Health at Work), 2017. The GESTIS Biological Agents Database — Compact information for occupational safety and health protection. Retrieved April 2020 from: https://oshwiki.eu/wiki/The_GESTIS_Biological_Agents_Database_%E2%80%93_compact_information_for_occupational_safety_and_health_protection

EU-OSHA (European Agency for Safety and Health at Work), 2018a. Workshop on the prevention of work-related diseases due to biological agents' exposure at work. Retrieved from 2 March 2020 from: https://osha.europa.eu/en/tools-and-resources/seminars/workshop-prevention-work-related-diseases-due-biological-agents

EU-OSHA (European Agency for Safety and Health at Work), 2018b. Alert and sentinel approaches for the identification of work-related diseases in the EU. Luxembourg: Publications Office of the European Union. doi:10.2802/869066

EU-OSHA (European Agency for Safety and Health at Work), 2019a. Biological agents and work-related diseases: Results of a literature review, expert survey and analysis of monitoring systems. Luxembourg: Publications Office of the European Union.

EU-OSHA (European Agency for Safety and Health at Work), 2019b. Exposure to biological agents and related health problems in animal-related occupations — Discussion paper. Luxembourg: Publications Office of the European Union.

EU-OSHA (European Agency for Safety and Health at Work), 2019c. Exposure to biological agents and related health problems in arable farming — Discussion paper. Luxembourg: Publications Office of the European Union.

EU-OSHA (European Agency for Safety and Health at Work), 2019d. Exposure to biological agents and related health effects in the waste management and wastewater treatment sectors — Discussion paper. Luxembourg: Publications Office of the European Union.

EU-OSHA (European Agency for Safety and Health at Work), 2019e. Exposure to biological agents and related health problems for healthcare workers — Discussion paper. Luxembourg: Publications Office of the European Union.

EU-OSHA (European Agency for Safety and Health at Work), 2019f. Biological agents and associated work-related diseases in occupations that involve travelling and contact with travellers — Discussion paper. Luxembourg: Publications Office of the European Union.

European Commission, 2012. Report on the current situation in relation to occupational diseases' systems in EU Member States and EFTA/EEA countries, in particular relative to Commission Recommendation 2003/670/EC concerning the European schedule of occupational diseases and gathering of data on relevant related aspects. Retrieved 28 October 2016 from: http://ec.europa.eu/social/BlobServlet?docId=9982&langId=en

European Commission, 2017. Evaluation of the practical implementation of the EU occupational safety and health (OSH) directives in EU Member States — Synthesis report. Brussels: European Commission. Retrieved April 2020 from: https://ec.europa.eu/social/main.jsp?catId=148&langId=en&moreDocuments=yes

Eurostat, 2010. Health and safety at work in Europe (1999-2007): A statistical portrait. Luxembourg: Publications Office of the European Union.

Feary, J., Cullinan, P., 2016. Laboratory animal allergy: A new world. Curr. Opin. Allergy Clin.Immunol. 16, 107-112.

Fiebelkorn, A.P., Seward, J.F., Orenstein, W., Diseases, R., 2014. A global perspective of vaccination of healthcare personnel against measles: Systematic review. Vaccine. 32, 4823-4839. doi:10.1016/j.vaccine.2013.11.005.A

Fijan, S., Šostar Turk, S., 2012. Hospital textiles, are they a possible vehicle for healthcare-associatedinfections? Int. J. Environ. Res. Public Health 9, 3330-3343. doi:10.3390/ijerph9093330

Fischer, I., Schurer, St., Jäckel R., Rieger, M.A., 2013. Epidemiology of work-related infectious diseases (Epidemiologie arbeitsbedingter Infektionskrankheiten). Bundesanstalt für Arbeitsschutz und Arbeitsmedizin (BAuA), Forschung Projekt F 5198/A91, Dortmund/Berlin/Dresden.

Förster, G., Germany´s national system for prevention of risks from biological agents: The role of the committee on biological agents and its cooperation with other bodies, presentation at the EU-OSHA workshop on the prevention of work-related diseases due to biological agents exposure at work. Retrieved April 2020 from: https://osha.europa.eu/sites/default/files/seminars/documents/4%20F%C3%B6rster.pdf

Fromme, H., Gareis, M., Völkel, W., Gottschalk, C., 2016. Overall internal exposure to mycotoxins and their occurrence in occupational and residential settings: An overview. Int. J. Hyg. Environ. Health 219, 143-165. doi:10.1016/j.ijheh.2015.11.004

Gabrio, T., 2010. Occurrence and health/allergological relevance of mould from the perspective of environmental medicine (Vorkommen und gesundheitlich-allergologische Relevanz von Schimmelpilzen aus der Sicht der Umweltmedizin) Allergologie 33, 101-108. doi:10.5414/ALP33101

Gangneux, J.-P., Adjidé, C.-C., Bernard, L., Botterel, F., Carel, A., Castel, O., Derouin, F., Hoarau, G., Labussière, H., Lafaurie, M., Millon, L., Pottecher, B., Thiebaut, A., Turco, M., Baron, R., 2012. Quantitative assessment of the fungal risk in the event of work in health establishments: Proposals for impact indicators for measures to manage the fungal infectious risk.(Appréciation quantitative du risque fongique en cas de travaux en établissements de santé: Propositions d'indicateurs d'impact des mesures de gestion du risque infectieux fongique). J. Mycol. Médicale/J. Med. Mycol. 22, 64-71. doi:10.1016/j.mycmed.2012.01.003

Garg, S.K., Mittal, S., Kaur, P., 2012. Dental unit waterline management: Historical perspectives and current trends. J. Investig. Clin. Dent. 3, 247-252.

Gerardi, D., 2010. Building-related illness. Clin. Pulm. Med. 17, 276-281. doi:10.1097/CPM.0b013e3181fa1448

Goniewicz, M., Włoszczak-Szubzda, A., Niemcewicz, M., Witt, M., Marciniak-Niemcewicz, A., Jarosz, M.J., 2012. Injuries caused by sharp instruments among healthcare workers: International and Polish perspectives. Ann. Agric. Environ. Med. 19, 523-527.

Gralton, J., McLaws, M.-L., 2010. Protecting healthcare workers form pandemic influenza: N95 or surgical masks? Crit. Care Med. 38, 657-667.

Green, B.J., Beezhold, D.H., 2011. Industrial fungal enzymes: An occupational allergen perspective. J. Allergy 2011, 682574. doi:10.1155/2011/682574

Haagsma, J.A., Tariq, L., Heederik, D.J.J., Havelaar, A.H., 2012. Infectious disease risks associated with occupational exposure: A systematic review of the literature. Occup. Env. Med. 69, 140-146.

Hadaway, L., 2012. Needlestick injuries, short peripheral catheters, and health care worker risks. J. Infus. Nurs. 35, 164-78. doi:10.1097/NAN.0b013e31824d276d

Hämäläinen, P., Takala, J., Saarela, K.L., 2007. Global estimates of fatal work-related diseases. Am. J. Ind. Med. 50, 28-41.

Health Council of the Netherlands, 2004. Dutch Expert Committee on Occupational Standards. Wheat and other cereal flour dusts. The Hague: Health Council of the Netherlands. Publication no. 2004/02OSH.

Health Council of the Netherlands, 2008. Prevention of work-related airway allergies. Recommended occupational exposure limits and periodic screening. The Hague: Health Council of the Netherlands. Publication no. 2008/03.

Health Council of the Netherlands, 2010. Endotoxins. Health-based recommended occupational exposure limit. The Hague: Health Council of the Netherlands. Publication no. 2010/04OSH.

Health Council of the Netherlands, 2011. Grain dust. Health-based recommended occupational exposure limit. The Hague: Health Council of the Netherlands. Publication no. 2011/13.

Health Council of the Netherlands, 2012. Advisory letter on health-based recommended occupational exposure limits for biological agents. The Hague: Health Council of the Netherlands. Publication no. 2012/35E (available at: http://www.gr.nl/en/publications/gezondearbeidsomstandigheden/advisory-letter-on-health-based-recommended-occupational).

Health Council of the Netherlands, 2014. Fungal alpha-amylase (derived from the fungus Aspergillus oryzae): Health-based recommended occupational exposure limit. The Hague: Health Council of the Netherlands. Publication no. 2014/25.

Health Council of the Netherlands, 2016. Flour dust from processed, de-hulled soybeans. Healthbased recommendation on occupational exposure limits. The Hague:Health Council of the Netherlands. Publication no. 2016/07.

Hersi, M., Stevens, A., Quach, P., Hamel, C., Thavorn, K., Garritty, C., Skidmore, B., Vallenas, C., Norris, S.L., Egger, M., Eremin, S., Ferri, M., Shindo, N., Moher, D., 2015. Effectiveness of personal protective equipment for healthcare workers caring for patients with filovirus disease: A rapid review. PLoS One 10, 1-17. doi:10.1371/journal.pone.0140290

HOSPEEM/EPSU, 2013. Promotion and support of implementation of Directive 2010/32/EU on the prevention of sharps injuries in the hospital and health care sector — Final report, 15 November 2013. Retrieved April 2020 from: http://www.epsu.org/sites/default/files/article/files/Final-Report-ICF-GHK-15-11-13-EN_TW-3.pdf

HOSPEEM/EPSU, 2019. Final report 2019 — Follow-up on the Directive 2010/32/EU on the prevention from sharps injuries in the hospital and healthcare sector. Retrieved April 2020 from: https://hospeem.org/activities/socialdialogue/final-report-followup-directive-201032eu-sharps-injuries-hospital-sector/

HSE (Health and Safety Executive), 2019. Infections at work. Retrieved July 2019 from: http://www.hse.gov.uk/biosafety/infection.htm

INRS, 2019. Tableaux des maladies professionnelles. Retrieved April 2020 from: http://www.inrs.fr/publications/bdd/mp.html

Jacob, S.A., Furgerson, S.P., 2012. Writing interview protocols and conducting interviews: Tips for students new to the field of qualitative research. The Qualitative Report 17, 1-10.

Jayanthi, P., Thomas, P., Bindhu, P.R., Krishnapillai, R., 2013. Prion diseases in humans: Oral and dental implications. N. Am. J. Med. Sci. 5, 399-403. doi:10.4103/1947-2714.115766

Johanning, E., Auger, P., Morey, P.R., Yang, C.S., Olmsted, E., 2014. Review of health hazards and prevention measures for response and recovery workers and volunteers after natural disasters, flooding, and water damage: Mold and dampness. Environ. Health Prev. Med. 19, 93-99. doi:10.1007/s12199-013-0368-0

Jones, M., 2015. Laboratory Animal Allergy in the Modern Era. Curr. Allergy Asthma Rep. 15, 1-8. doi:10.1007/s11882-015-0575-4

Keene, R.R., Hillard-Sembell, D.C., Robinson, B.S., Saleh, K.J., Novicoff, W.M., 2011. Occupational hazards to the pregnant orthopaedic surgeon. J. Bone Jt. Surg. Am. 93, e1411–e1415. doi:10.1016/S0021-9355(11)71103-1

Kolk, A., Koppisch, D., 2007. Endotoxin exposure at the workplace - evaluation of the BGIA exposure database MEGA (Endotoxinbelastung am Arbeitsplatz — Auswertung der BGIA Expositionsdatenbank MEGA). Gefahrstoffe — Reinhalt. Luft 67, 361-362.

Kortepeter, M.G., Seaworth, B.J., Tasker, S.A., Burgess, T.H., Coldren, R.L., Aronson, N.E., 2010. Health care workers and researchers travelling to developing-world clinical settings: Disease transmission risk and mitigation. Clin. Infect. Dis. 51, 1298-1305. doi:10.1086/657115

Korzeniewska, E., 2011. Emission of bacteria and fungi in the air from wastewater treatment plants: A review. Front. Biosci. (Schol. Ed.) 3, 393-407.

Kraus, G., Koppisch, D., 2007. Endotoxins in the natural fiber processing textile industry (Endotoxine in der Naturfaser verarbeitenden Textilindustrie). Gefahrstoffe — Reinhalt. Luft 67, 385-390.

Kuijer, P.P.F.M., Sluiter, J.K., 2010. Health and safety in waste collection: Towards evidence-based worker health surveillance. Am. J. Ind. Med. 53, 1040-1064. doi:10.1002/ajim.20870

Kuster, S.P., Shah, P.S., Coleman, B.L., Lam, P.P., Tong, A., Wormsbecker, A., McGeer, A., 2011. Incidence of influenza in healthy adults and healthcare workers: A systematic review and metaanalysis. PLoS One 6, 1-9. doi:10.1371/journal.pone.0026239

Lai, P.S., Christiani, D.C., 2014. Long term respiratory health effects in textile workers. Curr. Opin. Pulm. Med. J. 19, 152-157. doi:10.1097/MCP.0b013e32835cee9a.Long

Lavoie, J., Cloutier, Y., Lara, J., Marchand, G., 2007. RG-501: Guide on respiratory protection against bioaerosols Recommendations on its selection and use. Québec: Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST).

Lavoie, J., Neesham-Grenon, E., Debia, M., Cloutier, Y., Marchand, G., 2013. 804: Development of a control banding method for selecting respiratory protection against bioaerosols. Québec: Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST).

Louhelainen, K., Mäittälä, J., Kinnunen. B., 2017. Biological agents and the Finnish experience on OSH in agriculture. Presentation at the EU-OSHA 'Workshop on the prevention of work-related diseases due to biological agents exposure at work'. Retrieved April 2020 from: https://osha.europa.eu/sites/default/files/seminars/documents/6%20Louhelainen.pdf

Lupton, K., 2015. Preparing nurses to work in Ebola treatment centres in Sierra Leone. Br. J. Nurs. 24, 168-172. doi:10.12968/bjon.2015.24.3.168

Lynch, L., Spivak, E.S., 2015. The pregnant healthcare worker: Fact and fiction. Curr. Opin. Infect. Dis. 28, 362-368. doi:10.1097/QCO.0b013e3283638104

Mack, N., Woodsong, C., MacQueen, K.M., Guest, G., Namey, E., 2005. Qualitative research methods: A data collector's field guide. Durham, NC: Family Health International.

Mohan, S., Sarfaty, S., Hamer, D.H., 2010. Human immunodeficiency virus postexposure prophylaxis for medical trainees on international rotations. J. Travel Med. 17, 264-268. doi:10.1111/j.1708-8305.2010.00421.x

Monge-Maillo, B., López-Vélez, R., 2012. Migration and malaria in Europe. Mediterr. J. Hematol. Infect. Dis. 4. doi:10.4084/MJHID.2012.014

Montano, D., 2014. Chemical and biological work-related risks across occupations in Europe: A review. J. Occup. Med. Toxicol. 9, 28. doi:10.1186/1745-6673-9-28

Moscato, G., Pala, G., Boillat, M.A., Folletti, I., Gerth Van Wijk, R., Olgiati-Des Gouttes, D., Perfetti, L., Quirce, S., Siracusa, A., Walusiak-Skorupa, J., Tarlo, S.M., 2011. EAACI position paper: Prevention of work-related respiratory allergies among pre-apprentices or apprentices and young workers. Allergy Eur. J. Allergy Clin. Immunol. 66, 1164-1173. doi:10.1111/j.1398-9995.2011.02615.x

Moscato, G., Pala, G., Crivellaro, M., Siracusa, A., 2014. Anaphylaxis as occupational risk. Curr. Opin. Allergy Clin. Immunol. 14, 328-333.

Narasimhan, P., Wood, J., Macintyre, C.R., Mathai, D., 2013. Review article risk factors for tuberculosis. Pulm. Med. 2013, 11. doi:10.1155/2013/828939

Newman, K.L., Newman, L.S., 2012. NIH Public Access. Curr. Opin. Allergy Clin. Immunol. 12, 145150. doi:10.3851/IMP2701.Changes

Panosian, C., 2010. Courting danger while doing good: Protecting global health workers from harm. N. Engl. J. Med. 363, 2484-5. doi:10.1056/NEJMp1011407.

Pearson, C., Littlewood, E., Douglas, P., Robertson, S., Gant, T.W., Hansell, A.L., 2015. Exposures and health outcomes in relation to bioaerosol emissions from composting facilities: a systematic review of occupational and community studies. J. Toxicol. Environ. Health. B. Crit. Rev. 18, 43- 69. doi:10.1080/10937404.2015.1009961

Pedrosa, P.B.S., Cardoso, T.A.O., 2011. Viral infections in workers in hospital and research laboratory settings: A comparative review of infection modes and respective biosafety aspects. Int. J. Infect. Dis. 15, e366–e376. doi:10.1016/j.ijid.2011.03.005

Platt, L., Jolley, E., Rhodes, T., Hope, V., Latypov, A., Reynolds, L., Wilson, D., 2013. Factors mediating HIV risk among female sex workers in Europe: A systematic review and ecological analysis. BMJ Open 3, 14. doi:10.1136/bmjopen-2013-002836

Prester, L., 2011. Indoor exposure to mould allergens. Arh. Hig. Rada Toksikol. 62, 371-80. doi:10.2478/10004-1254-62-2011-2126

Quirce, S., Bernstein, J.A., 2011. Old and new causes of occupational asthma. Immunol. Allergy Clin. North Am. 31, 677–698.

Quirce, S., Sastre, J., 2011. New causes of occupational asthma. Curr. Opin. Allergy Clin. Immunol. 11, 80-85.

Quirce, S., Diaz-Perales, A., 2013. Diagnosis and management of grain-induced asthma. Allergy Asthma Immunol. Res. 5, 348-356.

Quirce, S., Vandenplas, O., Campo, P., Cruz, M.J., de Blay, F., Koschel, D., Moscato, G., Pala, G., Raulf, M., Sastre, J., Siracusa, A., Tarlo, S.M., Walusiak-Skorupa, J., Cormier, Y., 2016. Occupational hypersensitivity pneumonitis: An EAACI position paper. Allergy Eur. J. Allergy Clin. Immunol. 71, 765-779. doi:10.1111/all.12866

Raulf, M., 2016. Allergen component analysis as a tool in the diagnosis of occupational allergy. Curr. Opin. Allergy Clin. Immunol. 16, 96-100.

Raulf-Heimsoth, M., Sander, I., Kespohl, S., van Kampen, V., Brüning, T., 2011. Rare and new occupational inhalation allergens (Seltene und neue berufliche Inhalationsallergene). Allergologie 34, 27-32.

Raulf-Heimsoth, M., van Kampen, V., Kespohl, S., Sander, I., Merget, R., Brüning, T., 2012. Inhalation allergies in the workplace (Inhalationsallergien am Arbeitsplatz). Bundesgesundheitsblatt — Gesundheitsforsch. Gesundheitsschutz. 55, 363-372. doi:10.1007/s00103-011-1432-9

Rohr, A.C., Campleman, S.L., Long, C.M., Peterson, M.K., Weatherstone, S., Quick, W., Lewis, A., 2015. Potential occupational exposures and health risks associated with biomass-based power generation. Int. J. Environ. Res. Public Health. 12, 8542-8605. doi:10.3390/ijerph120708542

Rosenman, K., 2015. Occupational diseases in individuals exposed to metal working fluids. Curr. Opin. Allergy Clin. Immunol. 15, 131-6. doi:10.1097/ACI.0000000000000140

Rossouw, T.M., Van Rooyen, M., Louw, J.M., Richter, K.L., 2014. Blood-borne infections in healthcare workers in South Africa. South African Med. J. 104, 732-735. doi:10.7196/samj.8518

Seidler A, Nienhaus A, Diel R., 2005. Review of epidemiological studies on the occupational risk of tuberculosis in low-incidence areas. Respiration 72, 431-446.

Sennekamp, J., 2011. The current catalogue of antigens, clinical pictures and occupations at risk of exogenous allergic alveolitis (Der aktuelle Katalog der Antigene, Krankheitsbilder und Risikoberufe der exogen-allergischen Alveolitis). Atemw.-Lungenkrkh. 37, 238-249.

Sennekamp, J., Forster, F., 2012. Occupational exogenous allergic bronchiolo-bronchitis (Berufsbedingte exogen-allergische Bronchiolo-Bronchitis). Allergologie 35, 298-309.

Shaheen, M.A., Idrees, M., 2015. Evidence-based consensus on the diagnosis, prevention and management of hepatitis C virus disease. World J. Hepatol. 7, 616-627. doi:10.4254/wjh.v7.i3.616

Shannon, K., Strathdee, S.A., Goldenberg, S.M., Duff, P., Mwangi, P., Rusakova, M., Reza-Paul, S., Lau, J., Deering, K., Pickles, M.R., Boily, M.-C., 2015. Global epidemiology of HIV among

female sex workers: Influence of structural determinants. Lancet 385, 55-71. doi:10.1016/S0140-6736(14)60931-4

Smilowitz, N.R., Balter, S., Weisz, G., 2013. Occupational hazards of interventional cardiology. Cardiovasc. Revascularization Med. 14, 223-228. doi:10.1016/j.carrev.2013.05.002

Snape, D., Spencer, L., 2003. 'The foundations of qualitative research'. In: Qualitative research practice: A guide for social science students and researchers. J. Ritchie and J. Lewis (eds). London: Sage, pp. 1-23.

Spankie, S., Cherrie, J.W., 2012. Exposure to grain dust in Great Britain. Ann. Occup. Hyg. 56, 25-36. doi:10.1093/annhyg/mer084

Suwantarat, N.; Apisarnthanarak, A., 2015. Risk to healthcare workers with emerging diseases: Lessons from MERS-CoV, Ebola, SARS and avian flu. Curr. Opin. Infect. Dis. 28, 349-361. doi:10.1097/QCO.0b013e3283638104

Swords, P., 2011. A review of the established European practice in relation to biohazards associated with waste and waste-related biofuels. Proceedings of the 22nd Institution of Chemical Engineers Symposium on Hazards 2011 (HAZARDS XXII), Liverpool, 11-14 April 2011. Redhook, NY: Curran, 213-219.

US-EPA (United States Environmental Protection Agency), Indoor Air Facts No. 4 (revised) Sick Building Syndrome. Retrieved June 2020 from https://www.epa.gov/indoor-air-quality-iaq/indoor-air-facts-no-4-sick-building-syndrome.

Utsumi, M., Makimoto, K., Quroshi, N., Ashida, N., 2010. Types of infectious outbreaks and their impact in elderly care facilities: A review of the literature. Age Ageing 39, 299-305. doi:10.1093/ageing/afq029

Wallace, R.J., Gropp, J., Dierick, N., Costa, L.G., Martelli, G., Brantom, P.G., Bampidis, V., Renshaw, D.W., Leng, L., 2016. Risks associated with endotoxins in feed additives produced by fermentation. Environ. Health 15, 5. doi:10.1186/s12940-016-0087-2

Walser, S.M., Gerstner, D.G., Brenner, B., Bünger, J., Eikmann, T., Janssen, B., Kolb, S., Kolk, A., Nowak, D., Raulf, M., Sagunski, H., Sedlmaier, N., Suchenwirth, R., Wiesmüller, G., Wollin, K.M., Tesseraux, I., Herr, C.E.W., 2015. Evaluation of exposure-response relationships for health effects of microbial bioaerosols: A systematic review. Int. J. Hyg. Environ. Health 218, 577-589. doi:10.1016/j.ijheh.2015.07.004

Peters, W., Wester, F., 2004. Qualitative analysis: Principles and Procedures (Kwalitatieve analyse: uitgangspunten en procedures). Uitgeverij Coutinho (eds)

Wéry, N., 2014. Bioaerosols from composting facilities: A review. Front. Cell. Infect. Microbiol. 4, 42. doi:10.3389/fcimb.2014.00042

WHO (World Health Organization), 2014. Ebola virus disease — Spain. Disease outbreak news, 9 October 2014. Retrieved July 2019 from: https://www.who.int/csr/don/09-october-2014-ebola/en/

WHO (World Health Organization), 2018. Hepatitis B. Retrieved June 2019 from https://www.who.int/en/news-room/fact-sheets/detail/hepatitis-b

Wiggans, R.E., Evans, G., Fishwick, D., Barber, C.M., 2016. Asthma in furniture and wood processing workers: A systematic review. Occup. Med. 66, 193-201.

Wilson, D., 2015. HIV programs for sex workers: Lessons and challenges for developing and delivering programs. PLoS Med. 12, 1-11. doi:10.1371/journal.pmed.1001808

Wong, S.S.Y., Wong, S.C.Y., 2015. Ebola virus disease in nonendemic countries. J. Formos. Med. Assoc. 114, 384-398. doi:10.1016/j.jfma.2015.01.012

Woo, C.S.J., El-Nezami, H., 2016. Maternal-fetal cancer risk assessment of ochratoxin A during pregnancy. Toxins (Basel) 8, 87. doi:10.3390/toxins8040087

Younai, F.S., 2010. Health care: Associated transmission of hepatitis B and C viruses in dental care (dentistry). Clin. Liver Dis. 14, 93-104.

Zacharisen, M.C., Fink, J.N., 2011. Hypersensitivity pneumonitis and related conditions in the work environment. Immunol. Allergy Clin. North Am. 31, 769-786.

Zandi, M., Alavian, S-M., Bagheri-Lankarani, K., 2011. Hepatitis B prevention of the nurses: A review article. HealthMed 5, 1941.

Zukiewicz-Sobczak, W., 2013. The role of fungi in allergic diseases. Postep. Dermatologii i Alergol. 30, 42-45. doi:10.5114/pdia.2013.33377

Zukiewicz-Sobczak, W., Sobczak, P., Krasowska, E., Zwoliński, J., Chmielewska-Badora, J., Galińska, E.M., 2013a. Allergenic potential of moulds isolated from buildings. Ann. Agric. Environ. Med. 20, 500-503.

Zukiewicz-Sobczak, W., Chmielewska-Badora, J., Wróblewska, P., Zwoliński, J., 2013b. Farmers' occupational diseases of allergenic and zoonotic origin. Postep. Dermatologii i Alergol. 30, 311-315. doi:10.5114/pdia.2013.38361

Annex 1: Methodology of scientific literature search

Development of search strategy

A well-defined search strategy was employed, for which the strategy described in the project proposal (see the section 'Search strings as applied in the different databases' in this annex) was used as a starting point. However, after the first searches showed that the output of the searches was too large to handle, the search strategy was adapted so that it could limit the output to a number that could be handled during the following screening. This included restricting the search to 'Title and Abstract' or 'Title, Abstract and Keywords'. Furthermore, sometimes concepts were combined in a certain way (e.g. searching for biological agents and health effects instead of biological agents and/or health effects). In addition, separate searches were also performed for 'allergens' and 'other biological agents', so that the screening could be performed more efficiently.

During the development of the search strategy, the PubMed search engine was used as a starting point for the literature screening, after which the search was adapted to fit the requirements of the other databases (see 'Search strings as applied in the different databases'). The search strategy consisted of the following primary concepts (search strings, #), which are defined in more detail in the section 'Search strings as applied in the different databases':

1. reviews;
2. work-relatedness;
3. adverse health outcomes;
4. biological agents (separate searches for allergens and other biological agents);
5. publication date;
6. language;
7. monitoring systems;
8. databases;
9. EU Directive 2000/54/EC.

These concepts were combined to gather information on the following subjects:

- health effects or biological agents: ((#1 AND #2 AND (#3 OR #4)) AND #5 AND #6);
- monitoring systems: ((#7 AND #2 AND (#3 OR #4)) AND #6 AND #7);
- databases: ((#8 AND #2 AND (#3 OR #4)) AND #6 AND #7);
- EU Directive: ((#9 AND #2 AND (#3 OR #4)) AND #6 AND #7).

After the initial searches, alternative searches were also used to check the relevance separately in some cases. Furthermore, the searches for information on monitoring systems, databases and the EU directive were not limited to reviews, since this restriction did not result in any output. In addition, the websites of EU-OSHA, OECD and Eurostat were searched for relevant studies.

To check the performance of the search strategy, a set of systematic reviews that were expected to be found was identified (Haagsma et al., 2012; Montano et al., 2014; Walser et al., 2015; Wiggans et al., 2016), to optimise the search strings. As an example of the limitation of the review search, the paper of Eduard et al. (2012) was not retrieved through our searches, although it was expected to be found. This was because this paper contained none of the search terms, as defined in the concept 'review', in its text or keywords.

Initial screening of output literature search

A web-based publication-screening tool developed by TNO was used for most of the preliminary check, based on the output of the searches in the PubMed and Scopus databases. This tool was used to record all used search queries, the resulting publication details, the criteria used to select papers to be moved to the next step and the accordance of each publication to these criteria. It allowed an efficient, traceable and sustainable execution of the screening process by avoiding unnecessary manual handling and recording essential information in a database. Furthermore, it automatically removed the duplicates from

the output of the searches in the databases of PubMed and Scopus, after the output of the comparable searches were uploaded to the tool.

However, since the output of the searches in the OpenGrey and OSH-Update databases could not be exported to a file type that could then be imported into this tool, the output from these databases had to be screened manually. Details of the selected relevant publications were copied to a Word document from the OSH-Update search results (initial output as HTML files). Details of the selected relevant publications from the searches in the OpenGrey database were copied to a Word document directly from the output of the individual searches on the OpenGrey website.

An initial screening was performed to check publications retrieved from the literature search for relevance to the inclusion criteria, based on title and abstract, before the publications were retrieved and a full evaluation was performed. The following inclusion criteria were applied:

- description of exposure to biological agents and/or description of health effects due to exposure to biological agents in a work-related context;
- for the more specific searches for monitoring systems, databases or information on Directive 2000/54/EC, these subjects added to the first criterion;
- review of existing studies or case reports.

In the case of allergens, papers about food allergens and exotoxins from microorganisms were excluded, because food allergens fall outside the scope of the literature search and the allergenic effects of exotoxins were considered to be of less relevance in an occupational context. Furthermore, exotoxins are included as a search term for 'other biological agents' and were thus covered in the literature search as a whole.

After the project team discussed the inclusion criteria and evaluated a small sample of the output based on the inclusion criteria together, a project team member screened the papers on 'allergens' and another project team member screened the papers on 'other biological agents'. In cases of uncertainty, the paper was discussed within the project team.

Search strings as applied in the different databases

Information on biological agents and/or health effects

The proposed search strings shown below were for searching the PubMed database. The same keywords but different refinements were used for Scopus and the other databases to limit the publications found to acceptable numbers for review. These are indicated for each database separately in the sections below.

Definition of search terms (#):

1. Review:
    - PubMed: (meta analysis[Publication Type] OR meta analysis[Title/Abstract] OR meta analysis[MeSH Terms] OR review[Publication Type] OR review[Title/Abstract] OR search*[Title/Abstract])
    - Non-PubMed: ('meta analysis' OR meta-analysis OR review OR search)
2. Work-related: (occupation*[tiab] OR worker*[tiab] OR workplace*[tiab]) OR job*[tiab] OR work-related [tiab] OR 'working environment'[tiab] OR 'work environment'[tiab] OR 'work place'[tiab] OR 'work places'[tiab] OR 'work site'[tiab] OR 'work sites'[tiab])
3. Health effects:
    - Allergens: (allergy[Title/Abstract] OR sensitisation[Title/Abstract] OR asthma[Title/Abstract] OR rhinitis[Title/Abstract] OR 'atopic dermatitis' [Title/Abstract] OR 'hypersensitivity pneumonitis' [Title/Abstract] OR HP[Title/Abstract] OR 'extrinsic allergic alveolitis'[Title/Abstract] OR EAA[Title/Abstract] OR hypersensitivity[Title/Abstract])

- Other biological agents: (zoonose*[Title/Abstract] OR 'Infectious Disease Transmission' [Title/Abstract] OR 'communicable disease' [Title/Abstract] OR 'communicable diseases' [Title/Abstract] OR 'virus disease' [Title/Abstract] OR 'virus diseases' [Title/Abstract] OR 'bacterial infection' [Title/Abstract] OR 'bacterial infections' [Title/Abstract] OR 'parasitic disease'[Title/Abstract] OR 'parasitic diseases' [Title/Abstract] OR mycosis[Title/Abstract] OR mycoses[Title/Abstract] OR infection*[Title/Abstract] OR 'infectious disease'[Title/Abstract] OR 'infectious diseases'[Title/Abstract] OR 'organic dust toxic syndrome'[Title/Abstract] OR ODTS[Title/Abstract])

4. Biological agents:
   - Allergens: (allergen*[Title/Abstract] OR aeroallergen*[Title/Abstract])
   - Other biological agents: (bioaerosol*[Title/Abstract] OR 'biological agents'[Title/Abstract] OR 'biological agent'[Title/Abstract] OR 'organic dust'[Title/Abstract] OR 'organic dusts'[Title/Abstract] OR 'environmental microbiology'[MH] OR 'air-microbiology'[Title/Abstract] OR microorgan*[Title/Abstract] OR 'micro-organism'[Title/Abstract] OR 'micro-organisms'[Title/Abstract] OR 'virus*'[Title/Abstract] OR bacteria[Title/Abstract] OR fung*[Title/Abstract] OR yeast*[Title/Abstract] OR mould*[Title/Abstract] OR prion*[Title/Abstract] OR protozoic*[Title/Abstract] OR 'genetically modified organism'[Title/Abstract] OR GMO*[Title/Abstract] OR parasite*[Title/Abstract] OR helminth*[Title/Abstract] OR endotoxin*[Title/Abstract] OR exotoxin*[Title/Abstract] OR glucan*[Title/Abstract] OR mycotoxin*[Title/Abstract] OR 'biological hazard'[Title/Abstract] OR 'biological hazards'[Title/Abstract])
5. PubDate: >2009
6. Language: English OR German OR Dutch OR French OR Danish

PubMed:

- String health effects or biological agents: ((#1 AND #2 AND (#3 OR #4)) AND #5 AND #6)
  - Allergens
  - Other biological agents
- String health effects: #1 AND #2 AND #3 AND #5 AND #6
  - Allergens
  - Other biological agents
- String biological agents: #1 AND #2 AND #4 AND #5 AND #6
  - Allergens
  - Other biological agents
- String health effects and biological agents: #1 AND #2 AND #3 AND #4 AND #5 AND #6
  - Other biological agents

Scopus:

For Scopus, strings #1 to #4 were used first, where relevant. Then a selection was made for 'Publication year and 'Language'. Since large numbers were found, it was also decided to apply the 'TITLE-ABS-KEY' for all keywords and to further refine searches with DOCTYPE 'reviews'.

- String health effects or biological agents: (#3 OR #4) AND #1 AND #2 AND #5 AND #6
  - Allergens
- String health effects and agents: #1 AND #2 AND #3 AND #4 AND #5 AND #6
  - Other biological agents
- String health effects: #1 AND #2 AND #3 AND #5 AND #6
  - Allergens
- String biological agents: #1 AND #2 AND #4 AND #5 AND #6

- Allergens
- Other biological agents

OpenGrey:

For OpenGrey, fewer hits were found and, considering the expected type of studies searched for (e.g. thesis, reports), #1 (review) was excluded.

- String health effects or biological agents: ((#2 AND (#3 OR #4)) AND #5 AND #6)
  - Allergens
  - Other biological agents
- String health effects: #2 AND #3 AND #5 AND #6
  - Allergens
- String agents: #2 AND #4 AND #5 AND #6
  - Allergens

OSH-Update:

- String health effects or biological agents: ((#1 AND #2 AND (#3 OR #4)) AND #5 AND #6)
  - Allergens
  - Other biological agents
- String health effects: #1 AND #2 AND #3 AND #5 AND #6
  - Allergens
- String biological agents: #1 AND #2 AND #4 AND #5 AND #6
  - Allergens

Information on monitoring systems for biological agents and/or health effects

The proposed search strings shown below were for searching the PubMed database. The same keywords but different refinements were used for Scopus and the other databases, to limit the publications found to acceptable numbers for review. These are indicated for each database separately in the sections below.

Definition of search terms (#):

1. Review: not applicable
2. Work-related: (occupation*[tiab] OR worker*[tiab] OR workplace*[tiab]) OR job*[tiab] OR work-related [tiab] OR 'working environment'[tiab] OR 'work environment'[tiab] OR 'work place'[tiab] OR 'work places'[tiab] OR 'work site'[tiab] OR 'work sites'[tiab])
3. Health effects:
   - Allergens: (allergy[Title/Abstract] OR sensitisation[Title/Abstract] OR asthma[Title/Abstract] OR rhinitis[Title/Abstract] OR 'atopic dermatitis' [Title/Abstract] OR 'hypersensitivity pneumonitis' [Title/Abstract] OR HP[Title/Abstract] OR 'extrinsic allergic alveolitis'[Title/Abstract] OR EAA[Title/Abstract] OR hypersensitivity[Title/Abstract])
   - Other biological agents: (zoonose*[Title/Abstract] OR 'Infectious Disease Transmission' [Title/Abstract] OR 'communicable disease' [Title/Abstract] OR 'communicable diseases' [Title/Abstract] OR 'virus disease' [Title/Abstract] OR 'virus diseases' [Title/Abstract] OR 'bacterial infection' [Title/Abstract] OR 'bacterial infections' [Title/Abstract] OR 'parasitic diseases'[Title/Abstract] OR 'parasitic diseases' [Title/Abstract] OR mycosis[Title/Abstract] OR mycoses[Title/Abstract] OR infection*[Title/Abstract] OR 'infectious disease'[Title/Abstract] OR 'infectious diseases'[Title/Abstract] OR 'organic dust toxic syndrome'[Title/Abstract] OR ODTS[Title/Abstract])
4. Biological agents:

- Allergens: (allergen*[Title/Abstract] OR aeroallergen*[Title/Abstract])
- Other biological agents: (bioaerosol*[Title/Abstract] OR 'biological agents'[Title/Abstract] OR 'biological agent'[Title/Abstract] OR 'organic dust'[Title/Abstract] OR 'organic dusts'[Title/Abstract] OR 'environmental microbiology'[MH] OR 'air-microbiology'[Title/Abstract] OR microorgan*[Title/Abstract] OR 'micro-organism'[Title/Abstract] OR 'micro-organisms'[Title/Abstract] OR 'virus*'[Title/Abstract] OR bacteria[Title/Abstract] OR fung*[Title/Abstract] OR yeast*[Title/Abstract] OR mould*[Title/Abstract] OR prion*[Title/Abstract] OR protozoic*[Title/Abstract] OR 'genetically modified organism'[Title/Abstract] OR GMO*[Title/Abstract] OR parasite*[Title/Abstract] OR helminth*[Title/Abstract] OR endotoxin*[Title/Abstract] OR exotoxin*[Title/Abstract] OR glucan*[Title/Abstract] OR mycotoxin*[Title/Abstract] OR 'biological hazard'[Title/Abstract] OR 'biological hazards'[Title/Abstract])

5. PubDate: ≥2009
6. Language: English OR German OR Dutch OR French OR Danish

Monitoring systems:

- PubMed: ('monitoring system' [MH] OR monitoring[tiab])
- Scopus: ('monitoring system')
- OpenGrey: (monitoring)
- OSH-Update: (monitoring)

PubMed:

- String health effects or biological agents: ((#7 AND #2 AND (#3 OR #4)) AND #5 AND #6)
  - Allergens
  - Other biological agents
- String biological agents: (#7 AND #2 AND #4 AND #5 AND #6)
  - Other biological agents
- String health effects and biological agents: (#7 AND #2 AND #3 AND #4 AND #5 AND #6)
  - Other biological agents

Scopus:

For Scopus, strings #2 to #4 were used first, where relevant. Then a selection was made for 'Publication year and 'Language'. Since large numbers were found, it was decided to apply the 'TITLE-ABS-KEY' for all keywords.

- String health effects or biological agents: ((#3 OR #4) AND #7 AND #2 AND #5 AND #6)
  - Allergens
  - Other biological agents

OpenGrey:

- String health effects or biological agents: ((#3 OR #4) AND #7 AND #2 AND #5 AND #6)
  - Allergens
  - Other biological agents

OSH-Update:

- String health effects or biological agents: ((#7 AND #2 AND (#3 OR #4)) AND #5 AND #6)
  - Allergens
  - Other biological agents

Information on databases for biological agents and/or health effects

The proposed search strings shown below were for searching the PubMed database. The same keywords but different refinements were used for Scopus and the other databases to limit the publications found to acceptable numbers for review. These are indicated for each database separately in the sections below.

Definition of search terms (#):

1. Review: not applicable
2. Work-related: (occupation*[tiab] OR worker*[tiab] OR workplace*[tiab]) OR job*[tiab] OR work-related [tiab] OR 'working environment'[tiab] OR 'work environment'[tiab] OR 'work place'[tiab] OR 'work places'[tiab] OR 'work site'[tiab] OR 'work sites'[tiab])
3. Health effects:
    - Allergens: (allergy[Title/Abstract] OR sensitisation[Title/Abstract] OR asthma[Title/Abstract] OR rhinitis[Title/Abstract] OR 'atopic dermatitis' [Title/Abstract] OR 'hypersensitivity pneumonitis' [Title/Abstract] OR HP[Title/Abstract] OR 'extrinsic allergic alveolitis'[Title/Abstract] OR EAA[Title/Abstract] OR hypersensitivity[Title/Abstract])
    - Other biological agents: (zoonose*[Title/Abstract] OR 'Infectious Disease Transmission' [Title/Abstract] OR 'communicable disease' [Title/Abstract] OR 'communicable diseases' [Title/Abstract] OR 'virus disease' [Title/Abstract] OR 'virus diseases' [Title/Abstract] OR 'bacterial infection' [Title/Abstract] OR 'bacterial infections' [Title/Abstract] OR 'parasitic diseases'[Title/Abstract] OR 'parasitic diseases' [Title/Abstract] OR mycosis[Title/Abstract] OR mycoses[Title/Abstract] OR infection*[Title/Abstract] OR 'infectious disease'[Title/Abstract] OR 'infectious diseases'[Title/Abstract] OR 'organic dust toxic syndrome'[Title/Abstract] OR ODTS[Title/Abstract])
4. Biological agents:
    - Allergens: (allergen*[Title/Abstract] OR aeroallergen*[Title/Abstract])
    - Other biological agents: (bioaerosol*[Title/Abstract] OR 'biological agents'[Title/Abstract] OR 'biological agent'[Title/Abstract] OR 'organic dust'[Title/Abstract] OR 'organic dusts'[Title/Abstract] OR 'environmental microbiology'[MH] OR 'air-microbiology'[Title/Abstract] OR microorgan*[Title/Abstract] OR 'micro-organism'[Title/Abstract] OR 'micro-organisms'[Title/Abstract] OR 'virus*'[Title/Abstract] OR bacteria[Title/Abstract] OR fung*[Title/Abstract] OR yeast*[Title/Abstract] OR mould*[Title/Abstract] OR prion*[Title/Abstract] OR protozoic*[Title/Abstract] OR 'genetically modified organism'[Title/Abstract] OR GMO*[Title/Abstract] OR parasite*[Title/Abstract] OR helminth*[Title/Abstract] OR endotoxin*[Title/Abstract] OR exotoxin*[Title/Abstract] OR glucan*[Title/Abstract] OR mycotoxin*[Title/Abstract] OR 'biological hazard'[Title/Abstract] OR 'biological hazards'[Title/Abstract])
5. PubDate: ≥2009
6. Language: English OR German OR Dutch OR French OR Danish
7. Monitoring systems:
8. Databases:
    - PubMed: (database*[tiab] OR dataset*[tiab])
    - Non-PubMed: (database OR dataset OR database* OR dataset*)

PubMed:

- String health effects or biological agents: ((#8 AND #2 AND (#3 OR #4)) AND #5 AND #6)

  - Allergens
  - Other biological agents
- String biological agents: (#8 AND #2 AND #4 AND #5 AND #6)
  - Other biological agents
- String health effects and biological agents: (#8 AND #2 AND #3 AND #4 AND #5 AND #6)
  - Other biological agents

Scopus:

For Scopus, strings #2 to #4 were used first, where relevant. Then a selection was made for 'Publication year' and 'Language'. Since large numbers were found, we also decided to apply the 'TITLE-ABS-KEY' for all keywords.

- String health effects or biological agents: ((#3 OR #4) AND #8 AND #2 AND #5 AND #6)
  - Allergens
  - Other biological agents

OpenGrey:

- String health effects or biological agents: ((#3 OR #4) AND #8 AND #2 AND #5 AND #6)
  - Allergens
  - Other biological agents

OSH-Update:

- String health effects or biological agents: ((#8 AND #2 AND (#3 OR #4)) AND #5 AND #6)
  - Allergens
  - Other biological agents

Information on EU Directive 2000/54/EC

The proposed search strings shown below were for searching the PubMed database. The same keywords but different refinements were used for Scopus and the other databases to limit the publications found to acceptable numbers for review. These are indicated for each database separately in the sections below.

Definition of search terms (#):

1. Review: not applicable
2. Work-related: (occupation*[tiab] OR worker*[tiab] OR workplace*[tiab]) OR job*[tiab] OR work-related [tiab] OR 'working environment'[tiab] OR 'work environment'[tiab] OR 'work place'[tiab] OR 'work places'[tiab] OR 'work site'[tiab] OR 'work sites'[tiab])
3. Health effects:
   - Allergens: (allergy[Title/Abstract] OR sensitisation[Title/Abstract] OR asthma[Title/Abstract] OR rhinitis[Title/Abstract] OR 'atopic dermatitis' [Title/Abstract] OR 'hypersensitivity pneumonitis' [Title/Abstract] OR HP[Title/Abstract] OR 'extrinsic allergic alveolitis'[Title/Abstract] OR EAA[Title/Abstract] OR hypersensitivity[Title/Abstract])
   - Other biological agents: (zoonose*[Title/Abstract] OR 'Infectious Disease Transmission' [Title/Abstract] OR 'communicable disease' [Title/Abstract] OR 'communicable diseases' [Title/Abstract] OR 'virus disease' [Title/Abstract] OR 'virus diseases' [Title/Abstract] OR 'bacterial infection' [Title/Abstract] OR 'bacterial infections' [Title/Abstract] OR 'parasitic diseases'[Title/Abstract] OR 'parasitic diseases' [Title/Abstract] OR mycosis[Title/Abstract] OR mycoses[Title/Abstract] OR infection*[Title/Abstract] OR 'infectious disease'[Title/Abstract] OR 'infectious

diseases'[Title/Abstract] OR 'organic dust toxic syndrome'[Title/Abstract] OR ODTS[Title/Abstract])

4. Biological agents:
    - Allergens: (allergen*[Title/Abstract] OR aeroallergen*[Title/Abstract])
    - Other biological agents: (bioaerosol*[Title/Abstract] OR 'biological agents'[Title/Abstract] OR 'biological agent'[Title/Abstract] OR 'organic dust'[Title/Abstract] OR 'organic dusts'[Title/Abstract] OR 'environmental microbiology'[MH] OR 'air-microbiology'[Title/Abstract] OR microorgan*[Title/Abstract] OR 'micro-organism'[Title/Abstract] OR 'micro-organisms'[Title/Abstract] OR 'virus*'[Title/Abstract] OR bacteria[Title/Abstract] OR fung*[Title/Abstract] OR yeast*[Title/Abstract] OR mould*[Title/Abstract] OR prion*[Title/Abstract] OR protozoic*[Title/Abstract] OR 'genetically modified organism'[Title/Abstract] OR GMO*[Title/Abstract] OR parasite*[Title/Abstract] OR helminth*[Title/Abstract] OR endotoxin*[Title/Abstract] OR exotoxin*[Title/Abstract] OR glucan*[Title/Abstract] OR mycotoxin*[Title/Abstract] OR 'biological hazard'[Title/Abstract] OR 'biological hazards'[Title/Abstract])
5. PubDate: >2009
6. Language: English OR German OR Dutch OR French OR Danish
7. Monitoring systems: not applicable
8. Databases: not applicable

EU Directive 2000/54/EC:

- PubMed: ('EU directive'[TW] OR 2000/54/EC OR 'government regulation'[MH] OR 'Legislation as topic'[MH])
- Non-PubMed: ('EU directive' OR 2000/54/EC OR 'government regulation' OR 'Legislation as topic')

PubMed:

- String health effects or biological agents: ((#9 AND #2 AND (#3 OR #4)) AND #5 AND #6)
    - Allergens
    - Other biological agents

Scopus:

For Scopus, strings #2 to #4 were used first, where relevant. Then a selection was made for 'Publication year' and 'Language'. Since large numbers were found, it was decided to apply the 'TITLE-ABS-KEY' for all keywords.

- String health effects or biological agents: ((#3 OR #4) AND #9 AND #2 AND #5 AND #6)
    - Allergens
    - Other biological agents

OpenGrey:

- String health effects or biological agents: ((#3 OR #4) AND #9 AND #2 AND #5 AND #6)
    - Allergens
    - Other biological agents

OSH-Update:

- String health effects or biological agents: ((#9 AND #2 AND (#3 OR #4)) AND #5 AND #6)
    - Allergens
    - Other biological agents

ANNEX 2: Questionnaire about work-related diseases due to biological agents

Instructions for answering the questions

This questionnaire consists of four parts, namely:

- Part 1: General questions
- Part 2: National monitoring systems, sentinel and alert systems and national health provisions
- Part 3: Initiatives on (inter)national level
- Part 4: Description of cases

We do not expect from you as a respondent to provide us with a complete (literature) overview. We kindly ask you to use your current knowledge and expertise for answering the questions. We very much appreciate all information we can gather with regard to this topic, and thus also welcome suggestions sent by email.

Furthermore, when answering the questions of this questionnaire we would like to friendly ask you:

- To answer precisely and clearly
- To keep your answer as short as possible
- To answer each question

In case of open questions, we kindly ask you to fill in your answer in the accompanying text box. In case of multiple-choice questions (for instance Yes/No) we kindly ask you to select the appropriate answer.

In the final report, all results will be presented anonymously, your input will mainly be presented on the level of the country you represent.

For any questions or suggestions, you can contact eelco.kuijpers@tno.nl

Thank you for participating in this research.

Part 1: General questions

1) Name

_____

2) For which organisation/company do you work?

_____

3) What is your current working position(s)? (more answers possible)

- o Researcher
- o Policy-maker
- o Public administration
- o Occupational hygienist
- o Occupational physician
- o Other, namely: _____

4) Country you represent

_____

5) Via which network/contact did you receive this questionnaire? (more answers possible)
- o National focal point of EU-OSHA
- o Modernet
- o Perosh
- o EurWORK (Eurofound) network
- o Other, namely: _____

6) To what extent are you familiar with the topic biological agents in the workplace?
- o Much experience
- o Some experience
- o No experience

Part 2: National monitoring systems, sentinel and alert systems and national health provisions

In Europe various systems are used to monitor/register occupational exposures to substances and/or work-related diseases. Although information on exposure to biological agents and recording of diseases related to these exposures may not cover all exposures in all sectors, it is known that considerable progress has been made on characterising exposures in certain (emerging) professions, such as green jobs and home care.

In this part of the questionnaire we focus on existing monitoring systems (7 and 8) in European countries. Furthermore, we would like to get an idea of any (national) sentinel and alert systems (9) and public health provisions (10) that are in place.

Monitoring/registration systems: *The regular observation and recording of activities taking place in relation to occupational exposures to substances and/or work-related diseases. Existing systems for occupational diseases essentially have two main functions: monitor the trends in prevalence and incidence of occupational diseases and adequately alert OSH stakeholders of newly occurring occupational or work-related diseases. However, in general the monitoring is primarily aimed at 'established' occupational diseases and is often mainly related and limited to the compensation. A number of relevant infectious diseases are covered by (obligatory) recording systems (e.g. blood-borne diseases or tuberculosis) under other systems.*

7) Are you aware of a national monitoring system (or systems) **on work-related diseases** or accidents, in which work-related diseases caused by biological agents are (also) covered? An example is infectious diseases such as hepatitis B that occur due to blood contact.
- o Yes
- o No → proceed to the following question

If yes, please answer per known monitoring system (max. three) on work-related diseases the following questions. If you are familiar with more than three monitoring systems, please specify those three that you consider to be most relevant.

Monitoring system on work-related diseases 1:

a) Name/description of the system: _____

b) Is information gathered with this system publicly available?
- o Yes → please provide a reference/website: _____
- o No

c) In what language is the information from this system made available?

_____

d) Do you know which organisation and/or person to contact for further information on this system?
- **o** Yes → please specify: _____
- **o** No

e) Do you know in what way the information collected with this system is used (e.g. for research purposes, as input for policy-making, as input for prevention programmes)?
- **o** Yes → please specify: _____
- **o** No

Monitoring system on work-related diseases 2:

f) Name/description of the system: _____

g) Is information gathered with this system publicly available?
- o Yes → please provide a reference/website: _____
- o No

h) In what language is the information from this system made available?

_____

i) Do you know which organisation and/or person to contact for further information on this system?
- **o** Yes → please specify: _____
- **o** No

j) Do you know in what way the information collected with this system is used (e.g. for research purposes, as input for policy-making, as input for prevention programmes)?
- **o** Yes → please specify: _____
- **o** No

Monitoring system on work-related diseases 3:

k) Name/description of the system: _____

l) Is information gathered with this system publicly available?
- o Yes → please provide a reference/website: _____
- o No

m) In what language is the information from this system made available?

_____

n) Do you know which organisation and/or person to contact for further information on this system?
- **o** Yes → please specify: _____
- **o** No

o) Do you know in what way the information collected with this system is used (e.g. for research purposes, as input for policy-making, as input for prevention programmes)?
- **o** Yes → please specify: _____
- **o** No

8) Are you aware of a national monitoring system (or systems) **on worker exposure**, in which occupational exposure to biological agents is (also) covered?
- o Yes
- o No → proceed to the following question

If yes, please answer per known monitoring system on worker exposure (max. three) the following questions. If you are familiar with more than three monitoring systems, please specify the three that you consider to be most relevant.

Monitoring system on worker exposure 1:

a) Name/description of the system: _____

b) Is information gathered with this system publicly available?

- o Yes → please provide a reference/website: _____
- o No

c) In what language is the information from this system made available?

_____

d) Do you know which organisation and/or person to contact for further information on this system?

- **o** Yes → please specify: _____
- **o** No

e) Do you know in what way the information collected with this system is used (e.g. for research purposes, as input for policy-making, as input for prevention programmes)?

- **o** Yes → please specify: _____
- **o** No

Monitoring system on worker exposure 2:

f) Name/description of the system: _____

g) Is information gathered with this system publicly available?

- o Yes → please provide a reference/website: _____
- o No

h) In what language is the information from this system made available?

_____

i) Do you know which organisation and/or person to contact for further information on this system?

- **o** Yes → please specify: _____
- **o** No

j) Do you know in what way the information collected with this system is used (e.g. for research purposes, as input for policy-making, as input for prevention programmes)?

- **o** Yes → please specify: _____
- **o** No

Monitoring system on worker exposure 3:

k) Name/description of the system: _____

l) Is information gathered with this system publicly available?

- o Yes → please provide a reference/website: _____
- o No

m) In what language is the information from this system made available?

_____

n) Do you know which organisation and/or person to contact for further information on this system?

- **o** Yes → please specify: _____
- **o** No

o) Do you know in what way the information collected with this system is used (e.g. for research purposes, as input for policy-making, as input for prevention programmes)?

- **o** Yes → please specify: _____
- **o** No

Sentinel and alert systems: *Systems that identify emerging diseases and exposures, identify groups at risk and activities linked to exposure, target prevention, set up evidence-based prevention schemes, obtain trends information on some incidents and diseases. Examples are SHEO (Sentinel Health Event notification in Occupational health), SENSOR (Sentinel Event Notification of Occupational Risks) in the United States and SIGNAAL in the Netherlands.*

9) Are you aware of a sentinel or alert system (or systems), in which biological agents and/or work-related diseases due to biological agents are covered?

o Yes

o No → proceed to the following question

If yes, please answer per known sentinel/alert system (max. three) the following questions. If you are familiar with more than three sentinel/alert systems, please specify the three that you consider to be most relevant.

Sentinel/alert system 1:

a) Name/description of the system: _____

b) Is information gathered with this system publicly available?

o Yes → please provide a reference/website: _____

o No

c) Do you know which organisation and/or person to contact for further information on this system?

o Yes → please specify: _____

o No

d) Do you know in what way the information collected with this system is used (e.g. for research purposes, as input for policy-making, as input for prevention programmes)?

o Yes → please specify: _____

o No

Sentinel/alert system 2:

e) Name/description of the system: _____

f) Is information gathered with this system publicly available?

o Yes → please provide a reference/website: _____

o No

g) Do you know which organisation and/or person to contact for further information on this system?

o Yes → please specify: _____

o No

h) Do you know in what way the information collected with this system is used (e.g. for research purposes, as input for policy-making, as input for prevention programmes)?

o Yes → please specify: _____

o No

Sentinel/alert system 3:

i) Name/description of the system: _____

j) Is information gathered with this system publicly available?

o Yes → please provide a reference/website: _____

o No

k) Do you know which organisation and/or person to contact for further information on this system?

o Yes → please specify: _____

o No

l) Do you know in what way the information collected with this system is used (e.g. for research purposes, as input for policy-making, as input for prevention programmes)?
- **o** Yes → please specify: _____
- **o** No

(National) public health provisions: *These include health surveillance systems for individual workers, especially for (groups of) workers that are likely to be exposed to biological agents, guidelines for vulnerable (groups of) workers, or preventive measures such as mandatory or voluntary vaccination programmes for (groups of) workers (e.g. hepatitis B vaccination for laboratory workers or healthcare workers).*

10) Are you aware of national public health provisions (e.g. health surveillance of individual workers) that focus on or cover work biological agents?
- o Yes
- o No → proceed to the following question

If yes, please answer per known public health provision system (max. three) the following questions. If you are familiar with more than three public health provisions, please specify those three that you consider to be most relevant.

Public health provision 1:

a) Name/description of the provision: _____

b) Is information gathered with this provision publicly available, e.g. in a regular report?
- o Yes → please provide a reference/website: _____
- o No

c) Do you know which organisation and/or person to contact for further information on this provision?
- **o** Yes → please specify: _____
- **o** No

d) Do you know in what way the information collected with this public health provision is used (e.g. for research purposes, as input for policy-making, as input for prevention programmes)?
- **o** Yes → please specify: _____
- **o** No

Public health provision 2:

e) Name/description of the provision: _____

f) Is information gathered with this provision publicly available, e.g. in a regular report?
- o Yes → please provide a reference/website: _____
- o No

g) Do you know which organisation and/or person to contact for further information on this provision?
- **o** Yes → please specify: _____
- **o** No

h) Do you know in what way the information collected with this public health provision is used (e.g. for research purposes, as input for policy-making, as input for prevention programmes)?
- **o** Yes → please specify: _____
- **o** No

Public health provision 3:

i) Name/description of the provision: _____

j) Is information gathered with this provision publicly available, e.g. in a regular report?

- o Yes → please provide a reference/website: _____
- o No

k) Do you know which organisation and/or person to contact for further information on this provision?

- **o** Yes → please specify: _____
- **o** No

l) Do you know in what way the information collected with this public health provision is used (e.g. for research purposes, as input for policy-making, as input for prevention programmes)?

- **o** Yes → please specify: _____
- **o** No

Part 3: Initiatives on (inter)national level

In this part of the questionnaire we would like to identify relevant national policy or campaigns/strategies in your country. In addition, we would like to get an idea of the availability of national reviews and/or national or local networks of experts that focus on this topic. If you are aware of similar issues on an international level, these can also be mentioned, but this is not the main focus of our questionnaire.

Policy/regulation: *As stated before, in Europe, Directive 2000/54/EC (biological agents at work) lays down minimum requirements for the health and safety of workers exposed to biological agents at work. This directive classifies biological agents into four risk categories according to their potential to cause diseases and the possibilities of prevention and treatment. The directive also lays down requirements for notification of selected activities to authorities. For workers likely to be exposed to certain biological agents, employers have to keep records including information about exposure and health surveillance. However, these regulations are minimum requirements and have been implemented into national legislation. Some Member States have introduced Codes of Practice and guidelines for safe handling of biological agents including selected sectors and occupations.*

11) Are you aware of national policy with regard to biological agents, beyond the minimum regulations as indicated in Directive 2000/54/EC (e.g. code of practice, standard)?

- o Yes
- o No → proceed to the following question

If yes, please answer per known policy (max. three) the following questions. If you are familiar with more than three policies, please specify those three that you consider to be most relevant.

Policy 1:

a) Please provide a short description of this policy, including the aim of this policy:

_____

b) Is information on the policy publicly available?

- o Yes → please provide a reference/website: _____
- o No

c) Do you know which organisation and/or person to contact for further information on this policy?

- **o** Yes → please specify: _____
- **o** No

Policy 2:

d) Please provide a short description of this policy, including the aim of this policy:

_____

e) Is information on the policy publicly available?

- o Yes → please provide a reference/website: _____
- o No

f) Do you know which organisation and/or person to contact for further information on this policy?

- **o** Yes → please specify: _____

o No

Policy 3:

g) Please provide a short description of this policy, including the aim of this policy:

_____

h) Is information on the policy publicly available?
- o Yes → please provide a reference/website: _____
- o No

i) Do you know which organisation and/or person to contact for further information on this policy?
- **o** Yes → please specify: _____
- **o** No

Campaign/strategy: *Here we focus on for instance campaigns (a series of actions or events) focusing on prevention and/or raising awareness of health problems and diseases due to exposure to biological agents at work (e.g. with regard to prevention of needlestick injuries among healthcare workers, careful handling of human tissue by laboratory workers), or an inspection campaign with a focus on risks of biological agents in a specific sector/industry.*

12) Are you aware of national or local campaigns/strategies which focus on the risks of biological agents at work?
- o Yes
- o No → proceed to the following question

If yes, please answer per known campaign (max. three) the following questions. If you are familiar with more than three campaigns, please specify those three that you consider to be most relevant.

Campaign 1:

a) What is the focus of this campaign/strategy (e.g. aiming at a specific profession or sector, or a specific biological agent)?

_____

b) Is information about the campaign publicly available?
- o Yes → please provide a reference/website: _____
- o No

c) Do you know which organisation and/or person to contact for further information on this campaign?
- **o** Yes → please specify: _____
- **o** No

Campaign 2:

d) What is the focus of this campaign/strategy (e.g. aiming at a specific profession or sector, or a specific biological agent)?

_____

e) Is information about the campaign publicly available?
- o Yes → please provide a reference/website: _____
- o No

f) Do you know which organisation and/or person to contact for further information on this campaign?
- **o** Yes → please specify: _____
- **o** No

Campaign 3:

g) What is the focus of this campaign/strategy (e.g. aiming at a specific profession or sector, or a specific biological agent)?

_____

h) Is information about the campaign publicly available?
- o Yes → please provide a reference/website: _____
- o No

i) Do you know which organisation and/or person to contact for further information on this campaign?
- **o** Yes → please specify: _____
- **o** No

13) Are you aware of existing expert networks that pay specific attention to exposure to biological agents at the workplace and/or work-related diseases due to exposure to biological agents? For instance expert networks that focus on prevention of this type of occupational diseases, raising awareness with regard to this topic, or that can be consulted by occupational hygienists or occupational physicians that have a question with regard to this subject.

- o Yes
- o No → proceed to the following question

If yes, please answer per known network (max. three) the following questions. If you are familiar with more than three networks, please specify those three that you consider to be most relevant.

Network 1:

a) What is the focus of this network (e.g. a specific profession or sector, or a specific biological agent)?

_____

b) Is information on the network publicly available?
- o Yes → please provide a reference/website: _____
- o No

c) Do you know which organisation and/or person to contact for further information on this network?
- **o** Yes → please specify: _____
- **o** No

Network 2:

d) What is the focus of this network (e.g. a specific profession or sector, or a specific biological agent)?

_____

e) Is information on the network publicly available?
- o Yes → please provide a reference/website: _____
- o No

f) Do you know which organisation and/or person to contact for further information on this network?
- **o** Yes → please specify: _____
- **o** No

Network 3:

g) What is the focus of this network (e.g. a specific profession or sector, or a specific biological agent)?_____

h)

i) Is information on the network publicly available?
- o Yes → please provide a reference/website: _____
- o No

j) Do you know which organisation and/or person to contact for further information on this network?
- **o** Yes → please specify: _____
- **o** No

14) Are you aware of existing (major) national reports that are published with regard to exposure to biological agents and/or work-related diseases due to exposure to biological agents, or currently ongoing projects that focus on this subject? We are mainly interested in grey literature sources (e.g. reports of reviews performed on this topic, working papers, government documents).

- o Yes
- o No → proceed to the following question

If yes, please answer per known report/project (max. three) the following questions. If there are many of these reports or projects present for your country, please specify the three that you consider to be most important/relevant.

Report/project 1:

a) Name/description of the report/project

_____

b) Is this report and/or information on this project publicly available?
- o Yes → please provide a reference/website: _____
- o No

c) Do you know which organisation and/or person to contact for further information on this report or project?
- **o** Yes → please specify: _____
- **o** No

Report/project 2:

d) Name/description of the report/project

_____

e) Is this report and/or information of this project publicly available?
- o Yes → please provide a reference/website: _____
- o No

f) Do you know which organisation and/or person to contact for further information on this report or project?
- **o** Yes → please specify: _____
- **o** No

Report/project 3:

g) Name/description of the report/project

_____

h) Is this report and/or information of this project publicly available?
- o Yes → please provide a reference/website: _____
- o No

i) Do you know which organisation and/or person to contact for further information on this report or project?
- **o** Yes → please specify: _____
- **o** No

Part 4: Description of cases

Here we would like to get an idea of reported cases or clusters of occupational exposure to biological agents and/or work-related diseases caused by exposure to biological agents, as well as specific industries, sectors and/or professions that are considered to be (most) at risk. In general we are therefore asking for your expert opinion/judgement with regard to this topic.

15) Are you aware of reported cases with regard to work-related diseases due to exposure to biological agents (e.g. a case of farmer's lung disease at a pig farm, organic dust toxic syndrome (ODTS) related complaints reported in a vegetable seed plant or hypersensitivity pneumonitis reported among dental workers)?

o Yes
o No → proceed to the following question

If yes, please answer per known case (max. three) the following questions. If there are many of these cases described in your country, please specify the three cases that you consider to be most important/relevant.

Case 1:

a) Please give a short description of this case.

_____

b) Can you provide us with a reference for this case?
- o Yes → please provide a reference/website: _____
- o No

c) Do you know which organisation and/or person to contact for further information on this case?
- **o** Yes → please specify: _____
- **o** No

Case 2:

d) Please give a short description of this case.

_____

e) Can you provide us with a reference for this case?
- o Yes → please provide a reference/website: _____
- o No

f) Do you know which organisation and/or person to contact for further information on this case?
- **o** Yes → please specify: _____
- **o** No

Case 3:

g) Please give a short description of this case.

_____

h) Can you provide us with a reference for this case?
- o Yes → please provide a reference/website: _____
- o No

i) Do you know which organisation and/or person to contact for further information on this case?
- **o** Yes → please specify: _____
- **o** No

*An **'emerging occupational safety and health (OSH) risk'** is often defined as any occupational risk that is both new and increasing. By new, it means that the risk was previously unknown and is caused by new processes, new technologies, new types of workplaces, or social or organisational change; or a*

long-standing issue is newly considered to be a risk due to changes in social or public perceptions; or new scientific knowledge allows a long standing issue to be identified as a risk. The risk is increasing if the number of hazards leading to the risk is growing; or the likelihood of exposure to the hazard leading to the risk is increasing (exposure level and/or the number of people exposed); or the effect of the hazard on workers' health is getting worse (seriousness of health effects and/or the number of people affected).

16) For which occupation(s) do you consider exposure to biological agents at the workplace to be an emerging risk, for which more awareness should be generated? (more answers possible)

- o Waste treatment (including composting)
- o Wastewater treatment (including sewage)
- o Biotechnology
- o Laboratories (including laboratory animal workers)
- o Health care (human and veterinary)
- o Education (schools)
- o Childcare/day care
- o Agriculture
- o Food processing
- o Outdoor workers
- o Workers travelling to other countries as part of their work
- o Wood industry
- o Detergent industry
- o Metal industry (metalworking fluids)
- o Other, namely: _____
- o Not applicable

17) Which biological agent (or agents) do you consider to be most important (and therefore for instance should be taken into account in specific campaigns on this subject in the (near) future), and why?

- o Not applicable → proceed to the following question
- o Biological agent I: _____ Why? _____
- o Biological agent II: _____ Why? _____
- o Biological agent III: _____ Why? _____
- o Biological agent IV: _____ Why? _____
- o Biological agent V: _____ Why? _____

18) Which work-related disease (or diseases) caused by biological agents do you consider to be most important (and therefore for instance should be taken into account in specific campaigns on this subject in the (near) future), and why?

- o Not applicable → proceed to the following question
- o Work-related disease I: _____ Why? _____
- o Work-related disease II: _____ Why? _____
- o Work-related disease III: _____ Why? _____
- o Work-related disease IV: _____ Why? _____
- o Work-related disease V: _____ Why? _____

19) Do you have any other issues with regard to this topic, which need to be mentioned?

- o Yes, namely: _____
- o No

We thank you for your help in completing this questionnaire.

ANNEX 3: Methodology of the interviews (task 2)

Qualitative research approach

This study used a qualitative research approach (Jacob and Furgerson, 2012). This approach is especially useful when aiming for an in-depth investigation of specific topics and for learning the perspectives of the individuals participating in a study. This is important, because a better understanding of examples of OSH policy and its facilitating and hindering factors is needed for designing effective policy measures to protect and promote the health and safety of workers.

Procedure

Considering the broad types of national context regarding policies, the consortium selected 25 people involved in existing policies concerning work-related diseases due to biological agents from five EU Member States, to gather a thorough view of these policies in different European countries. As the focus was on countries with reputable knowledge of and the infrastructure to deal with exposures to biological agents, Denmark, Finland, France, Germany and the Netherlands were chosen (five experts per country) for the research.

To ensure representation of experts who worked in several disciplines, the consortium recruited participants working in the academic, policy and practice/consultancy fields in each country for the interviews. The relevant experts were identified through consultations between the consortium members and associated project collaborators, which led to a list of potential interviewees, which was discussed and agreed on with EU-OSHA and its national focal point in each participating country. The experts were subsequently approached by email or telephone and invited to participate. The selection was restricted to people with a background in occupational hygiene, occupational epidemiology, recognition of occupational diseases, workplace adjustment, and measurement and health monitoring, with the main focus on OSH and workplace prevention (as opposed to general infection control or medical treatment).

Participants

In total, 25 experts involved in existing policies on work-related diseases due to biological agents in five EU Member States (five experts per country) took part in the study. Table 5 summarises the most important characteristics of the experts, who worked predominantly as (1) researchers (including professors); (2) advisors or consultants; and (3) directors, chiefs or managers. In addition, the experts were mainly employed in a national institute in the field of occupational health.

Table 5: Characteristics of the interview participants

Characteristics	Denmark	Finland	France	Germany	Netherlands	Total
Number of experts	5	5	5	5	5	25
Function:						
Advisor/consultant	4	—	1	—	1	6
Researcher/scientist	—	1	—	3	2	6
Director/chief/manager	—	2	2	2	—	6
Professor	1	1	1	—	1	4
Medical/occupational physician	—	1	1	—	1	3

Characteristics	Denmark	Finland	France	Germany	Netherlands	Total
Type of organisation:						
National institute	4	3	4	1	2	14
Insurance	—	—	—	4	—	4
University	—	1	—	—	2	3
Ministry	—	1	—	—	1	2
Hospital	1	—	1	—	—	2
Field of work:						
Occupational health	5	3	3	5	3	19
Public health	—	—	1	—	2	3
Both	—	2	1	—	—	3
Discipline:						
Consultancy/practice	3	2	2	—	1	8
Academic/research	1	2	1	—	3	7
Policy	1	—	2	—	1	4
Combination	—	1	—	5	—	6

Interviews

The interviews were semi-structured and conducted either online via Skype or face to face. An interview schedule was used to introduce the participants in advance to the different subject areas specified; however, further areas that arose spontaneously were followed up and explored. The following areas were covered in each interview: the work and work-related background of the participant with regard to dealing with biological agents at work; the participant's experience of existing sectoral policy measures to prevent and protect workers from the risk of adverse health effects caused by biological agents at work; the participant's view on existing policy at a national level to prevent and protect workers from adverse health effects caused by biological agents at work (attention was also paid to unintended exposures and emerging risks); and mechanisms of influencing policy and existing knowledge gaps. Each interview began with some general questions, for example 'Could you tell me more about your work experience or knowledge of dealing with biological agents at work?' and 'What experience do you have of ongoing policy measures to prevent and protect workers from the risk of adverse health effects caused by biological agents at work?' The interviews also addressed the facilitating and hindering factors of (the implementation of) existing policies/policy measures, and their transferability.

To ensure that the experts were equally prepared for the interviews, an introductory document clarifying the definitions and concepts to be used during the interviews, with a list of examples of policy measures, was sent to the participants before the interviews. The introductory document described OSH policy as 'a number of basic principles that helps lay down guidance, practices and solutions initiated by public authorities and other OSH actors designed to protect, promote and restore the health and safety of

workers. Examples are training and information, awareness-raising and prevention, regulation and policy planning, monitoring and inspection and financing'. Subsequently, an overview of several types of policy and concrete policy measures was presented.

Instructions document for the interviewers

To ensure the quality of the interviews, it was essential that the interviewers were well prepared and appeared competent during the interview. Furthermore, it was important that all interviews were performed in a comparable manner. Therefore, in addition to the interview schedule, an instructions document entitled 'Instructions for interviewers' was developed for the interviewers. This document contained information for the interviewers on how to (1) prepare themselves for the interviews; (2) conduct the interviews; and (3) deliver the results of the interviews to TNO. Lastly, the 'Instructions for interviewers' document provided information on the instructions that were given via Skype to each interviewer prior to conducting his/her first interview.

Instructions for the interviewers via Skype

In each country, the interviews were conducted by the same (trained) interviewer from the project partner institutes, who had worked in the field of work-related diseases or qualitative research for several years.

To ensure that the interviewers' performances were comparable, in addition to the interview schedule and the 'Instructions for interviewers' document, all interviewers received instructions from the coordinator of task 2 via Skype or telephone. During this meeting, the methodological approach of the study (conducting qualitative interviews) was discussed, as well as the aims of the research and the topics and questions in the interview schedule. Participants were also told that the coordinator of task 2 would be available for questions and extra skills training if needed during the interview period.

Quality check

A quality check took place after each interviewer's first interview. This was conducted individually by the coordinator of task 2 via Skype and took 30-60 minutes. The aims of the quality check were to ensure that (1) the fieldwork was carried out consistently and (2) the interview schedule allowed the participant sufficient opportunities to cover relevant experiences. During the Skype session, the following topics were discussed:

- Process: How was the interviewer's experience of the interview?
- Content: In the opinion of the interviewer, was it possible to cover all the relevant topics in the interview schedule?
- Length of the interview: In the opinion of the interviewer, was the length of the interview adequate?

The highlights of each of these conversations were documented, and the interviewers' relevant experiences were shared. It appeared that it was not necessary to adapt the interview schedule on the basis of the first experiences.

Data analysis

All interviews were recorded on a digital voice recorder. The recordings of the interviews were fully transcribed and then translated into English. The translated transcripts formed the basis for the thematic analysis carried out for the purpose of answering the research questions (Snape and Spencer, 2003; Wester and Peters, 2004). In the first phase of data analysis, examples of OSH policy mentioned by the experts were identified and the related data were grouped into broad categories (i.e. facilitating factors and hindering factors) on the basis of the study objective. In the second phase, concepts, variables and classifications were selected, using keywords that identified the most important topics in the study. Initially, only the interviews of one country were analysed, which resulted in a provisional codebook (a description of the content and structure of the data analysis). The provisional codebook was then examined and verified through an analysis of the remaining interviews of the other countries, which led to the provisional codebook being supplemented as needed with other important, recurring concepts.

ANNEX 4: Methodology of the focus groups (task 3)

Focus group discussions

The use of focus groups is part of a qualitative methodology used for exploring the range of perspectives of a specific topic that exist within a community or subgroup. The dynamics among the participants of the focus groups provide a setting in which there is room for discussion, which deepens the understanding of a topic. The participants can build on the input provided by others, and this allows them to reflect on their own attitudes and behaviour. A focus group discussion is often led by one researcher (the moderator); a second researcher (the note-taker) takes detailed notes on the discussion. A principal advantage of focus groups is that they yield a large amount of information over a relatively short period of time. Mack et al. (2005) emphasise that focus group discussions are especially effective for accessing a broad range of views on a specific topic. However, focus groups are less suitable for eliciting individual experiences, opinions, feelings and in-depth responses with nuances and contradictions; individual interviews are better suited for this.

Procedure

Denmark, Finland, France, Germany and the Netherlands were chosen as the countries in which the focus groups were to be held, as they are known to have reputable knowledge of, and the infrastructure to deal with, exposure to biological agents in the workplace. The focus groups were coordinated by TNO, arranged in each of the countries by the project partners and run by appropriate OSH intermediaries in the native language. Each project partner was informed of the objectives and time frame of the project and the support they would receive from the overall project team to deliver the expected results.

One focus group session was held in each country. In each country, an experienced moderator with the necessary experience and content knowledge to lead the focus group session in their country was provided, as well as a second interviewer whose main task was to register and facilitate the discussion outcomes. Based on the objectives of the task, TNO developed a discussion guide, which included detailed, uniform instructions for the moderators and the second interviewers. Additional instructions were provided for the selection and invitation of participants, the focus group script and data handling. TNO arranged a Skype or telephone meeting to give instructions to the moderators and second interviewers, during which special attention was paid to the manner in which the focus groups should be organised and carried out, and which questions should be asked.

A detailed script was developed about what to achieve — and how — in the focus groups. Within each focus group, the following topics were discussed:

1. Introduction and practical matters, including the aim of the meeting.
2. Prioritisation of current risks with regard to the prevention of work-related diseases due to biological agents that require additional action/policy measures. This was done using predefined categories and Post-it® notes, and through a more in-depth discussion. A detailed list of biological agents and related diseases was used as the starting point for discussion, and, prior to the focus groups with the moderators, a list based on agent categories (task 1) was used to ensure that every expert fully understood the list. The experts were asked to place Post-it® notes on a whiteboard containing an overview of the list comprising agent categories to identify the top priorities, with a maximum of five stickers for the animal breeders/carers/handlers sector, three stickers for the waste treatment sector and three stickers for the healthcare sector. This was followed by an in-depth discussion of the answers.
3. Recommendations for policy measures for current risks: exploration of recommendations for policies for the agent category/risk that has been identified as the top priority in need of additional action/policy measures per sector. This was conducted using a predefined list and Post-it® notes, and through a more in-depth discussion. Table 6 gives an overview of the different types of policies used, with relevant examples, which was available only to the moderators. These types of policy categories were previously used in task 2.

4. Prioritisation of emerging risks, with regard to work-related diseases due to biological agents that require additional action/policy measures. This was carried out using a predefined list and Post-it® notes, and through a more in-depth discussion. The emerging risks used in these tables were previously identified in task 1 and were based on the results of the questionnaire. The interviewed experts' experiences from task 2 regarding emerging risks were also used.
5. Recommendations for policy measures for emerging risks: exploration of recommendations for policies for the emerging risk that has been identified as the top priority in need of additional action/policy measures per sector. This was carried out using a predefined list and Post-it® notes, and through a more in-depth discussion.
6. Summary of the focus group discussion.

On the basis of the first experiences in the Netherlands and Finland, the focus groups' experiences and specific points requiring attention were shared with the other countries during preparations for their focus group sessions.

Table 6: Types of policy and examples of policy/policy measures discussed during focus groups

Types of policy	Examples of policy/policy measures
Training and information	▪ Training programmes specific to risks in the workplace, such as those related to the measures below ▪ Training of worker representatives and other enterprise actors
Awareness-raising	▪ Campaigns regarding a certain topic, such as the prevention of needlestick injuries
OSH prevention	▪ Guidelines for risk assessment of biological agents at work ▪ Guidelines for safe handling of biological agents or prevention measures in certain sectors or occupations ▪ Immunisation campaigns ▪ Promotion of hygiene measures (e.g. disinfection of hands/boots) to prevent or reduce the accidental transfer or release of a biological agent in the workplace ▪ Promotion of environmentally sound management policies for the safe collection, storage and disposal of waste by workers in the workplace ▪ Availability of hand-washing systems and boot scrubbers, PPE, specific clothing and other equipment ▪ Availability of means for safe collect, store and dispose of waste (e.g. the use of secure and identifiable containers) after suitable treatment if appropriate ▪ Confinement measures, such as restricted access, black-white areas and decontamination
Health surveillance	▪ Biomonitoring and regular medical examinations
Regulation and policy planning	▪ National plans or strategies covering biological agents at work and/or the prevention of (specific) health problems ▪ Specific regulations, for example for specific tasks and sectors ▪ Setting an OEL ▪ Certifications

Types of policy	Examples of policy/policy measures
Monitoring and inspection	▪ Notification/monitoring of work-related diseases ▪ Workplace inspections, inspection campaigns ▪ Measurement of biological agents in workplaces, for example in measurement campaigns ▪ Record-keeping of exposure measurements and health surveillance ▪ National registers and reports covering the above
Financing	▪ Providing subsidies for workplace improvements ▪ Providing subsidies for the development of guidance or other OSH action

Participants

Each focus group session consisted of a group discussion, by means of a semi-structured discussion guide, for 2-3 hours with around eight professionals from OSH services, labour inspections, occupational hygiene services and trade unions.

In total, 39 experts participated in the focus group discussions (see Table 7). The experts from most countries were familiar with biological agents in more than one sector and thus able to participate in discussions on topics in multiple sectors. Only the experts from Finland reported no overlap in expertise.

In Denmark, nine experts participated, seven of whom were familiar with the animal breeders/carers/handlers sector, five of whom knew the waste treatment sector, and six of whom were familiar with the healthcare sector. Finland invited nine experts, but unfortunately two waste treatment experts were unable to participate. Therefore, in total, seven experts took part; three had expertise in the animal breeders/carers/handlers sector, one in the waste treatment sector and three in the healthcare sector. In France, nine experts participated in the focus groups sessions. Six experts were familiar with the animal breeders/carers/handlers sector, four with waste treatment and four with the healthcare sector. The moderators in Germany reported one cancellation. Therefore, Germany had six participants in its focus group sessions; one with expertise in the animal breeders/carers/handlers sector, two in the waste treatment sector and four in the healthcare sector. In the Netherlands, eight experts participated in the focus group sessions; four with expertise in animal breeders/carers/handlers, three in waste treatment and five in health care. In general, most experts had more than 10 years' experience of biological agents.

Overall, an equal number of experts were familiar with the animal breeders/carers/handlers and healthcare sectors, but a smaller number of experts were familiar with the waste treatment sector.

Table 7: Number of focus group participants and their familiarity with the three sectors

Country	Number of participants in total	Familiar with animal breeders/carers/handlers	Familiar with waste treatment	Familiar with health care
Denmark	9	7	5	6
Finland	7	3	1	3
France	9	6	4	4
Germany	6	2	3	5

Country	Number of participants in total	Familiar with animal breeders/carers/handlers	Familiar with waste treatment	Familiar with health care
Netherlands	8	4	3	5
Total	39	22	16	23

Moderators and second interviewers

The moderators and second interviewers for the focus groups in the five different countries were:

- Netherlands: moderator, Nicole van Kesteren (TNO); second interviewer, Suzanne Spaan (TNO);
- Finland: moderator, Kyösti Louhelainen (FIOH); second interviewer, Jani Ruotsalainen (FIOH);
- France: moderator, Juliette Bloch (ANSES); second interviewer, Isabelle Vanrullen (ANSES);
- Denmark: moderator, Vivi Schlünssen (AU); second interviewer, Christiane Beer (AU);
- Germany: moderator, Frank Diederich (BAuA); second interviewer, Dierk-Christoph Pöther (BAuA).

Table 8 presents information regarding the focus group sessions conducted and the dates of the meetings.

Table 8: Meeting dates

Date of meeting	Country
15 May 2017	Netherlands
16 May 2017	Finland
18 May 2017	Germany
28 May 2017	Denmark
2 June 2017	France

Denmark

A total of nine participants joined the focus group in Denmark. Overall, there was a very friendly and cheerful atmosphere, as many participants knew each other from previously working together. The atmosphere was also productive; nobody was afraid to speak, and the participants confirmed each other's remarks or added different aspects to the topic. There was mutual respect, everyone had the opportunity to express their thoughts, and no negative comments were made on different opinions. The dynamics among the participants created a very productive atmosphere. This was also strengthened by the fact that all the participants had at least one or two areas of expertise that overlapped with those of other participants but still had their own specific area of knowledge. Owing to the time limit (some participants had to catch a train to Copenhagen), some parts of the interview were not covered. However, we do not feel that this had a negative impact on the outcome of the focus group discussion, as the main parts were covered.

Finland

Although nine participants were invited, unfortunately only seven participants attended the meeting. One participant representing an occupational health service for a large waste treatment provider had to cancel about 3 weeks before the meeting because of another business meeting. She tried to organise another expert, but this did not work out. The second cancellation, from the waste treatment group, came as a surprise. The expert was supposed to come from an environmental service provider of waste treatment plants. The person in charge promised to send an expert but, the day before the meeting, the contact person called and said that all the experts had urgent business elsewhere and could not participate. At such extremely short notice, the only possible expert from FIOH qualified to replace the missing participant was unfortunately not able to participate. Not having the two experts on waste treatment present naturally affected the results of the waste treatment group, although there was good input from the participating experts during the discussions. The other two branches were represented fairly well, although the agricultural group's participation was slightly less prominent than that of the healthcare group.

France

In total, nine participants participated in the focus group session. Overall, the discussion was good, pleasant and constructive. The participants included an expert from a trade union; an occupational prevention expert from an animal laboratory working with piggeries, and poultry and chicken houses; a health and safety worker from waste treatment; occupational physicians with all-round expertise and occupational physicians from the healthcare sector; an expert in medicine and occupational health; a physician and head of a monitoring and alert system; an occupational health and safety inspector from the Ministry of Agriculture; and an expert in the prevention of waste and human health. The key impressions of the project team involved were that:

- similarities existed between the measures that were suggested to address current risks and emerging risks;
- microbiological risks were 'invisible' compared with other risks, although these were not necessarily seen as emerging;
- a professional perspective was important in any preventive action, independent of the sector involved, from information and training to facility and equipment design, protection in the workplace and professional practices;
- capacity-building is needed in consulting, follow-up and inspections;
- the organisation of work can either increase or decrease both current and emerging risks.

Germany

The meeting had six participants. Throughout the meeting and during the break, there was a lively, pleasant and constructive discussion. All participants had wide-ranging knowledge of the occupational issues related to biological agents as well as in-depth knowledge of their occupational branch specialisation, that is, animal husbandry, health care, or recycling and waste treatment. The focus group discussion yielded results on current risks, OSH policies against current risks, emerging risks and OSH policies against emerging risks. By explaining and underlining the 'current' and 'emerging' parameters, it was possible to have two separate discussions and to keep overlapping topics and arguments between current and emerging issues.

Netherlands

Eight participants joined the focus group session. Overall, the discussion in the focus group was good. The experts discussed a great deal of topics, although not every topic could be discussed as thoroughly as was hoped because of time constraints. When observing the experts during the assignment of prioritising current risks, it became clear that they felt that answering the questions on the prioritisation of the current risks by means of Post-it® notes was too complex. As a consequence, the participants did not want to use the Post-it® notes for this task and preferred a group discussion. Furthermore, during the discussion, it was noticed that the participants identified risks specifically/more frequently in terms of high-risk activities or high-risk processes within a sector (such as accidents with needles, and

problems with specific processes in waste treatment, such as collection and sorting) and less frequently from the perspective of a certain biological agent and/or health effect. For instance, the OSH professionals from the waste treatment sector indicated that they generally describe their exposure to biological agents as a complex mixture of all kinds of agents, without identifying specific agents. Because of this, the participants experienced difficulties in identifying risks by means of specific biological agent categories; thus, focusing on a specific biological agent instead of the high-risk activity or process was the best way forward for a fruitful discussion.

As this focus group discussion was the first of the five discussions organised, the experts shared their experiences with the project partners to optimise the script for the focus group and informed them of what they could do if they experienced the same things during their focus group session.

Instructions for moderators and second interviewers

The moderators and second interviewers were provided with an instructions document prior to the focus group session, which included information on how to successfully lead a focus group.

The instructions document included the following topics:

- Preparation: moderators and interviewers were asked to prepare by reading Mack et al. (2005) and understanding the purpose and approach of a focus group.
- Instructions via Skype (Week 19; 8-12 May).
- Conducting the focus group interview:
  - before the focus group session: familiarise yourself with the participants;
  - delivering the focus group session: tips for a successful meeting;
  - after the focus group session: summarise the different parts of the focus group discussion.
- Delivery of the results to TNO: the moderators and interviewers in the different countries were responsible for providing summaries of the discussions.

In addition, TNO trained the moderators and second interviewers in each country on how to conduct the focus group session. To ensure that the interviewers' performance was comparable, in addition to the focus group script and the 'Instructions for moderators and second interviewers' document, all moderators and second interviewers received instructions from the coordinator of task 3 via Skype or telephone. During this meeting, the methodological approach of the study (conducting focus group discussions) was discussed, as well as the aims of the research and the topics and questions in the focus group script. It was also mentioned that the coordinator of task 3 would be available during the focus group period for questions and extra skills training if needed.

Data analysis

The results of the focus groups were categorised and analysed on the basis of the following criteria: (1) sector; and (2) current versus emerging risks. The data, as provided by the project partners, were reviewed twice, after which they were categorised (generating multiple coding categories to obtain a broad perspective of the data, e.g. the different categories of the hierarchy of control). Focused coding was then used to eliminate, combine or subdivide the coding categories, and to look for repeated ideas and larger themes that connected the codes, to obtain a better idea of what common themes emerged in the responses to the specific topics and to find any deviations from these patterns (e.g. based on countries). A sum score was used to quantify the Post-it® notes and obtain a country-specific ranking. Priority 1 scored three points, Priority 2 received two points and Priority 3 received one point.

The experts in the Netherlands and Finland had difficulties in identifying specific agent categories and focused on the activities with the most risks related to biological agents. In addition, the experts from Denmark, Finland and the Netherlands categorised the additional policy measures discussed into types of policy using the predefined categories, whereas the experts in Germany prioritised (only) the policy types in a similar way to that of the agent categories (in sequence of importance), and the experts from France did not provide a summary of the appendices. Thus, for both France and Germany, a necessary step during the analytical phase was to categorise the additional policy measures discussed during their

focus group discussions, to be able to present the results in a similar way and compare them with those of the other countries. This approach was consequently applied in the analyses presented in Chapters 3, 4 and 5 (which present the results) of this report as recommendations on additional policy measures.

To be able to provide an overview of the high-priority risks according to the experts from the five countries, a sum score was calculated. The high-priority risks in each country were assigned points based on their ranking: the biological agent category selected by the experts as their first priority scored 3 points. Subsequently, their second priority scored 2 points, and their third priority scored 1 point. The points were counted for each biological agent category, leading to a total sum score that showed which risks the experts considered the highest priorities.

ANNEX 5: Examples of policy measures for different sectors as indicated by the experts during the interviews

Table 9: Animal-related occupations — overview of policy measures labelled by experts as 'more successful'

Country	Sector	Policy and aim	Context	Target group	Policy measures	Transferability
Denmark Expert 3	Animal farming	Measures to limit dust in sties on pig farms, to prevent respiratory diseases among farmers	Pig farms	Farmers: owners of pig farms and their workers	• Pamphlet about working in a piggery • Consultants explain to farmers the conclusions that they should draw from it	—
Denmark Expert 5	Animal farming	Measures to prevent MRSA infection among farmers on pig farms	Pig farms	Farmers: owners of pig farms and their employees	• More extensive guidance, based on the Danish Health Authority guidelines • Website with information • When new situations occur, assessment of whether or not guidelines need to be updated	Yes, or at least heavily inspired by the policy (all work environment authority guidelines)
France Expert 1	Animal farming	Measures to improve prevention of rare diseases from biological agents among humans and animals (e.g. Q fever)	Animal farms	Farmers and their animals	• Surveys on animal and human health • Monitoring of people who are in contact with biological agents	—

Country	Sector	Policy and aim	Context	Target group	Policy measures	Transferability
					• Prevention management advice based on laboratory work	
Denmark Expert 4	Animal farming	Measures to prevent MRSA infection on pig farms and the spreading of MRSA during inspections	Pig farms	Inspectors visiting pig farms	• Guidelines for inspectors on how to perform surveillance and protect themselves • Assessment of how important it is to go into places and limit unnecessary risks for inspectors • Training	Yes, the guidelines are transferable
Denmark Expert 3	Animal farming	Measures to prevent the spreading of MRSA and other bacteria, fungi and viruses among consultants visiting farms	Animal farms	Occupational safety consultants on farms	• Guidelines on how to behave while visiting farms (protective clothing, overshoes, washing hands, 24 hours between visiting stables) • A video and instructions	Unclear, although materials can easily be copied
France Expert 1	Animal farming; forestry; veterinarians	Exchange of measures to ensure warning signs (alerts of diseases), to prevent the spread of emerging zoonotic	Professions in contact with animals	Farmers, including ranchers, foresters, workers in animal husbandry, environment professionals and	Network with (occupational) health service professionals participating in multidisciplinary teams (veterinarians, GPs,	Yes, but it depends on the professionals' ability to work together (in

Country	Sector	Policy and aim	Context	Target group	Policy measures	Transferability
		diseases of which registration is not mandatory (e.g. psittacosis, Lyme disease, Q fever, endocarditis)		workers in zoological parks	occupational physicians) for a quick exchange of information	multidisciplinary teams)
France Expert 3	Slaughterhouses/ abattoirs; meat industry	Measures to prevent the spread of BSE among workers in the meat industry	Meat industry	Prevention stakeholders and workers in the meat industry (slaughterhouses, rendering companies, etc.)	• Training on what we know about BSE, preventive measures • Information pamphlet	—
Netherlands Expert 1	Academic research/ laboratories (laboratory animal workers)	Measures to prevent laboratory animal allergies within the academic setting	Animal laboratories at universities in the Netherlands	Researchers and laboratory animal caretakers	• Equipment for cleaning cages • Ventilation systems • Protective clothing	Good, although it is not clear if this is taking place
France Expert 1	Wildlife work	Measures to promote a culture of prevention of biological risks among wildlife workers	Wildlife work	Field professionals in wildlife work	• Training directly in the local occupational field	—

Table 10: Animal-related occupations — overview of policy measures labelled by experts as 'less successful'

Country	Sector	Policy and aim	Context	Target group	Policy measures	Transferability
Netherlands Expert 3	Slaughter-houses/ abattoirs	Measures to prevent respiratory problems through exposure to, for example, endotoxins	Slaughterhouses	Slaughterhouse workers	• Other techniques for cutting meat • Additional disinfection procedures (hygiene) for slaughtering processes	Like those of other countries Employment conditions are considered the responsibility of both employers and workers
Netherlands Expert 1	Animal farming	Measures to prevent allergies through exposure to fungi and animals in the agricultural industry	Agricultural industry in the Netherlands, for example farms (cow sheds and/or pigsties), riding schools, tomato greenhouses, manure heaps	Farmers, farm workers and other workers	• Lack of measures; worker has to leave job as soon as he/she has an allergy (to avoid exposure)	Similar to other countries

Table 11: Waste treatment — overview of policy measures labelled by experts as 'more successful'

Country	Sectors	Policy and aim	Context	Target group	Policy measures	Transferability
France Expert 5	Wastewater treatment; road and waterworks; forestry; social agriculture; greening/ gardening/ landscaping	Measures to prevent leptospirosis infection from contaminated water	Professions working with water	Drain workers, wastewater treatment plant workers, workers in the water and forestry sectors, outdoor workers, MSA workers	• Information • Vaccinations	Yes, vaccine was developed in other countries
Denmark Expert 1	Wastewater treatment/ sewage treatment	Measures to prevent gastrointestinal problems among sewage workers in Copenhagen municipality	Sewage system and sewage treatment plants	Sewage workers	• Sewage-handling guidelines • Special guidelines to avoid high-pressure water cleaning • Vaccination rules (hepatitis, tetanus)	—

Table 12: Waste treatment — overview of policy measures labelled by experts as 'less successful'

Country	Sector	Policy and aim	Context	Target group	Policy measures	Transferability
Denmark Expert 1	Waste treatment	Measures to prevent health problems among workers in recycling facilities	Recycling facilities	Recycling workers	• Rules and guidelines on how to work in a recycling facility • Recommendation to avoid high-pressure water cleaning	Yes

Table 13: Health care — overview of policy measures labelled by the experts as 'more successful'

Country	Sector	Policy and aim	Context	Target group	Policy measures	Transferability
Denmark Expert 2	Health care	Measures to prevent needlestick injuries among healthcare staff (hepatitis C, hepatitis B, HIV)	Hospitals	Healthcare personnel	• Vaccination • Information • Training	Yes: vaccinations, knowledge, information and training are transferable
Finland Expert 3	Health care	Measures to prevent needlestick injuries and thus blood-borne infections	Health care	Primarily nurses, laboratory nurses and physicians	• Guide and factsheet on how to prevent sharps injuries in health care	Yes
France Expert 2	Care and welfare	Measures to prevent respiratory and gastrointestinal epidemics among the elderly, by increasing hand hygiene of personnel in retirement homes	Retirement homes	Personnel in retirement homes End target group: residents	• Intensified information programme on good hand hygiene at work	—
France Expert 3	Health care	Measures to prevent Ebola virus infection among healthcare workers	Health sector	Healthcare workers, priority hospitals	• Quick assessment (evaluation) of what is needed and training in all related fields • PPE guidelines • Development of protective clothing by a work group in contact with manufacturers	—
France Expert 5	Health care	Measures to prevent blood exposure accidents and blood-borne infections (e.g. AIDS, hepatitis B infection) among healthcare professionals	Health sector	Healthcare professionals	• Risk education/ information • Vaccination rules for caregivers • National surveillance of accident types/ circumstances, prioritising	Yes, the greatest challenge is making people receptive to newly developed equipment and changing habits

Country	Sector	Policy and aim	Context	Target group	Policy measures	Transferability
					prevention of risks • Development of PPE	Vaccination does not have to be obligatory; it could merely be strongly recommended
Germany Expert 3	Health care; care and welfare	Measures to prevent infections from pathogens (e.g. hepatitis B, those that cause children's diseases, zoonotic pathogens, and those that cause exotic and tropical diseases) among workers in healthcare and day-care centres	Hospitals and day-care centres	Workers, company doctors and employers	• Consultation on vaccination • Vaccination of workers	—
Netherlands Expert 4	Health care	Measures to prevent infectious diseases, such as influenza, in hospitals	Academic hospitals	Primarily patients, secondarily workers	• Seasonal flu vaccinations	Good; international literature is important for vaccination policy
Netherlands Expert 4	Health care	Measures to prevent infectious diseases through, for example, hygienic work in hospitals	Academic hospitals	Primarily patients, secondarily workers	• Hygienic work practices	—

Table 14: Health care — overview of policy measures labelled by experts as 'less successful'

Country	Sector	Policy and Aim	Context	Target group	Policy measures	Transferability
Netherlands Expert 2	Health care	National guidelines prepared by Infection Prevention Society to prevent infectious diseases in Dutch healthcare institutions	Dutch healthcare institutions	Nursing staff	• Hospital hygiene, for example hand disinfection	—

Table 15: Arable farming — overview of policy measures labelled by experts as 'more successful'

Country	Sector	Policy and aim	Context	Target group	Policy measures	Transferability
Denmark Expert 3	Arable farming	Measures to promote working safely in agriculture, to prevent health problems (e.g. respiratory diseases, allergies, sore hands) among farmers	Agriculture	Farmers: farm owners and their workers	• APV workplace risk assessment, providing information on risks in specific workplace • Recommendations to improve risk management • Demonstrations/try-outs of latest developments in protection materials for farmers, showing what is available • Training of safety representatives	—
Finland Expert 1	Arable farming	Measures to prevent farmer's lung and other diseases related to mould growth and bacteria among farmers	Agriculture, specifically storage methods for hay and grain and processing methods for animal feed, litter or grains	Farmers (entrepreneurs)	• Education/information regarding the importance of working methods to reduce the risk of mould growth and bacteria • Revision of OSH recommendations/blue book for occupational health inspections	Yes

Country	Sector	Policy and aim	Context	Target group	Policy measures	Transferability
France Expert 1	Arable farming	Measures to reduce exposure to biological agents (often endotoxins) in agricultural companies with sick employees (respiratory diseases, fever)	Agriculture	Agricultural companies receiving health complaints from workers End target group: workers	• Research and advice: local measurements, advice and assistance provided to improve work processes to prevent infection	—
Germany Expert 4	Arable farming; forestry	Measures to promote safety technology and OSH in the workplace to prevent infectious diseases and allergies (by bacteria, fungi, viruses, bioaerosols, human obligate pathogens and zoonoses), provided by the agriculture accident insurance institutes	Agriculture, forestry and all companies for which an insurance association is responsible	Workers, supervisors and owners of agricultural companies, and their spouses or life partners in the company and in agricultural businesses	• Consultancy and advice for companies • Helpdesk (telephone) • Loose leaf collection and instruction manual • Template for implementation • Worker qualifications • Symposia and presentations • Inspections • Monitoring implementation of countermeasures and systematic evaluation • Research projects (e.g. collection of exposure data and cases of occupational diseases for systematic evaluation)	Yes, but other countries face different challenges. The policy needs to be adapted to the different legal and organisational conditions of other countries

Table 16: Laboratories — overview of policy measures labelled by experts as 'more successful'

Country	Sector	Policy and aim	Context	Target group	Policy measures	Transferability
France Expert 4	Laboratories	Measures to prevent infection and spread of biological agents among laboratory workers	Laboratory	Mainly laboratory workers, also visitors	• 2-hour sensitising course on working in a laboratory for new workers • Security rules regarding protective suits and equipment against animal bites, cutting, etc. • Security procedures for entering and leaving a level (L2, L3), such as showering, changing suits, etc. • Air pressure rules for different biological agents • Empowerment course on safety when working for the very first time with a specific biological agent • Regulations for visitors on washing hands, visiting farms • Training of maintenance staff	Yes, the rules are set by WHO and also need to be followed in other countries (good laboratory practice)
France Expert 4	Laboratories	Measures to record and analyse accidents occurring in the laboratory, with the aim of improving prevention methods	Laboratory	All workers in laboratories	• Systematic registration of accidents • Review of local hygiene with security group to determine preventive measures needed (4/year) • Review of working conditions by	—

Country	Sector	Policy and aim	Context	Target group	Policy measures	Transferability
					security groups (3-4/year) • Advice to work groups on new agents, including to a sanitary work doctor, applying a level of protection	
Germany Expert 2	Laboratories	Measures to promote the application of work protection laws and directives for laboratories, provided by an accident insurance association, to prevent respiratory or skin infections, allergies, irritations and toxic effects of pathogens (Risk Group 2 and higher)	Laboratories, insured by an insurance association	Safety officers, employers and workers	• Consultation • Laboratory inspections • In-house field measurements • Implementation of countermeasures • Seminars and information • Vaccination of workers	—
Netherlands Expert 2	Laboratories	Measures to prevent risk of tuberculosis infection and the spread of tuberculosis	Laboratories at academic hospitals	Workers	Guidelines and protocols for laboratory design, gowning procedures and how to handle infectious materials	Good, because the measures are partly the result of legislation at the national and international levels
Denmark Expert 4	Laboratories	Measures to prevent infection from genetically modified biological agents among inspectors of gene technology laboratories	Gene technology laboratories	Inspectors visiting laboratories	Guidelines on following the rules of the company that is being visited	—

Table 17: Laboratories — overview of policy measures labelled by experts as 'less successful'

Country	Sector	Policy and aim	Context	Target group	Policy measures	Transferability
France Expert 4	Laboratories	Measures to prevent infection from needlestick injuries, and pitting, biting and cutting accidents in the laboratory	Laboratory	Laboratory workers	• Protective gloves and other technological tools • Security procedures (e.g. using scissors instead of scalpels)	—

Table 18: Policies related to moisture damage/mould problems in buildings (not sector specific) — overview of policy measures labelled by experts as 'more successful'

Country	Sector	Policy and aim	Context	Target group	Policy measures	Transferability
Finland Expert 2	All sectors	Measures to improve diagnostics of occupational diseases related to moisture damage and mould	Buildings, mainly offices with moisture damage	Care personnel, mainly physicians and nursing personnel in occupational health services, and local government pension institutes of the country	• Revision of diagnostic criteria and compensation criteria of occupational diseases that are related to moisture damage and mould	Yes, if adapted to the operating environment of the country
Finland Expert 3	All sectors	Measures to reduce moisture damage and associated adverse health effects	Workplaces	• People working in workplaces with indoor air problems • OSH inspectors	• Two guidebooks with guidelines: no 1, workplaces; no 2, best practices in examining patients • New guidelines through FIOH training • Updated instructions for inspectors	Yes (though these problems are quite typical of Finland)

Country	Sector	Policy and aim	Context	Target group	Policy measures	Transferability
Finland Expert 4	General population; care and welfare; education	Measures to recognise microbial exposure in homes, day-care centres and schools, and the related adverse health effects	Homes, day-care centres and schools	Health protection authorities (inspections) and health care (diagnosing/screening activities)	• Guidelines, physicians' training materials for occupational and basic health care • Recommendations and instructions containing reference data on microbial growth • Data on the qualitative and quantitative links between microbial exposure and health	Partly: information on health and links to adverse health effects is transferable
Finland Expert 4	All sectors; construction industry	Measures to fill knowledge gaps related to the construction of healthy buildings	Construction of healthy buildings, for instance in terms of moisture control and indoor air quality	Decision-makers, health protection authorities, healthcare professionals and construction industry professionals	• Training card for construction workers related to moisture control • Updated criteria for healthy buildings (by Tampere University of Technology) • Work packages aimed at filling knowledge gaps and developing instructions and guidelines • Information for the Prime Minister's Office	Partly in a European/Nordic context: data obtained on air purifiers, biocides and healthy building criteria are transferable

Country	Sector	Policy and aim	Context	Target group	Policy measures	Transferability
					on what problems are still observed	
Finland Expert 5	Education; care and welfare; healthcare	Usage of FIOH 'Indoor Air Group' concept, a cooperative and project-style approach, involving representatives of every stakeholder of a building (including workers), for solving indoor air problems due to moisture damage and mould in workplaces	Workplaces with indoor air problems	All stakeholders (employers, workers, property management) of buildings with indoor air problems, in the public sector (schools, day-care centres, hospitals and other public municipal facilities)	• Training and information projects funded by the Finnish Work Environment Fund in the hospital sector and in schools	Yes

Table 19: Various sectors — overview of policy measures labelled by experts as 'more successful'

Country	Sector	Policy and aim	Context	Target group	Policy measures	Transferability
Germany Expert 1	Transport/ logistics	Measures to support businesses, provided by an accident insurance association, to prevent respiratory infections, allergies and irritations from pathogens and allergens from trade products	Trade and goods logistics related to businesses, insured by an insurance association	Policy-makers, safety officers, employers and workers	• Field safety assessments and surveillance • Helpdesk (telephone) for questions from the field • On-the-spot seminars, presentations and conferences on work safety • In-house field measurements and implementation of countermeasures • Sample analysis and systematic (effect) evaluation	Yes, but it requires comparable sharing and logistics of information on cases of occupational diseases and a similar organisational in-house structure
Finland Expert 1	Wood industry	Measures to reduce mould and bacteria exposure in the wood-processing industry and to prevent farmer's lung and asthma	Wood-processing industry, specifically plywood and sawmills	Wood-processing workers	• Written guide for workers	Yes, although measurement work will need to be redone in each country

Country	Sector	Policy and aim	Context	Target group	Policy measures	Transferability
Netherlands Expert 3	Food industry	Measures to prevent allergies through exposure to enzymes	Bakeries	Workers	• Surveillance projects to monitor/continue monitoring workers' health • Technological solutions, such as the production of liquid applications or larger particles that are less likely to be deposited in the respiratory tract • Ventilation systems • Dosing systems	—
Germany Expert 3	Health care; agriculture	Measures to promote the application of OSH regulations in health care and agriculture, to prevent infectious diseases (e.g. hepatitis, Ebola, HIV infection, tuberculosis, and particularly those from Risk Groups 3 and 4)	Healthcare and agriculture	Employers, safety officers, and company doctors	• Sets of technical rules and practical guidelines that will help the target group to correctly apply OSH regulations	No, the dual system has historical roots in Germany and it may not be possible to implement it in other countries. However, the principle of entrusting accident insurance institutes with preventive tasks is a good regulatory idea, which may be applicable to other countries

Country	Sector	Policy and aim	Context	Target group	Policy measures	Transferability
Germany Expert 5	Metal industry; wood industry	Measures on occupational safety in metalwork to prevent health problems such as respiratory and skin allergies and irritation from bacteria (e.g. MRSA, Gram-negative) and fungi, provided by accident insurance institutes	Metalwork and woodwork industry	Manufacturers and companies insured by accident insurance, machine workers	• Leaflets and brochures on technical rules • Information sheets used as an aid in risk assessment • 'Small' publications as low-threshold information, to support users such as machine workers • Seminars (basic courses, training and advanced training courses) • Research on exposure and cases of occupational diseases • Field safety assessments and evaluation	Yes

Table 20: Sector-transcending policies — overview of policy measures labelled by experts as 'more successful'

Country	Sector	Policy and aim	Context	Target group	Policy measures	Transferability
France Expert 2	General population (including workers)	Measures to predict flu epidemics	General population	General population	• Regional flu observation groups: surveillance by field actors (sentinel practitioners, emergency services, etc.), grouped with viral surveillance of the Pasteur Institute, and pharmaceutical statistics • Model with premature warning criteria about the duration, intensity and peak of epidemics	Yes, and it has been transferred — the Euro Flu Net was based on this model
Finland Expert 2	All sectors	Measures to improve the effectiveness of screening practices for diagnosing occupational asthma or identifying at-risk individuals	Many different areas, such as food production, agriculture, biotechnology and work involving animals	Occupational physicians	• Revision of guidelines (blue book) on determining which screening practices to use to diagnose occupational asthma or identify at-risk individuals	Yes, certain elements can be adapted to the operating environment (way in which an occupational health service is organised) in a country

Country	Sector	Policy and aim	Context	Target group	Policy measures	Transferability
Finland Expert 5	All sectors	Strategic training for occupational health services on how to manage issues related to exposure to biological agents; measures regarding both prevention and provision of care	Occupational health services, all sectors in which biological exposure is a possibility	Occupational physicians, nurses, other OSH experts, physiotherapists, psychologists at occupational health centres	• Training and information as a statutory element in all sectors and industries, including in unexpected circumstances • Proactive and preventive measures: information on risks involved and essential protective measures • Provision of care: provision of assistance after an accident or an uncontrollable exposure situation	Yes
France Expert 3	All sectors (excluding health care; biotechnology; research laboratories)	Measures to prevent biological agents at work, by INRS	Workplaces	Network for the Prevention of Occupational Accidents and Occupational Diseases: occupational physicians, prevention stakeholders, workers, etc.	• Training programme for risk awareness and assessment of biological agents at work, for all diseases and all sectors except the health sector and specific sectors (biotechnology sector or research labs)	Yes, this approach already exists in, for instance, the United Kingdom

ANNEX 6: Policy measures based on the focus groups (task 3)

Table 21: Overview of different policy measures mentioned during different focus groups for current and emerging risks in animal-related occupations, waste treatment and health care current and emerging risks

Type of risk	Sector	Policy measure suggested by experts
Current	Animal-related occupations/ Farming	**OSH prevention**: ▪ Finland has a unique system, FOHS, for raising awareness, providing information, education, advice and guidance in regard to PPE, monitoring and performing frequent health checks on farms. A case of **farmer's lung** (a type of hypersensitivity pneumonitis induced by intense or repeated inhalation of organic dust) was described, for which FOHS performed health checks. Unfortunately, the experts noted that not all farms are covered by this service (coverage is estimated at 30-60 %). 'Joining is voluntary; active farmers do join the system, but those who would benefit the most do not make use of this system.' In addition, the Finnish experts explained that FOHS can give recommendations regarding a person's ability or suitability to work, given specific risks in the work environment. This is especially relevant to vulnerable workers. The Finnish experts agreed that this is a good opportunity for employer support. If an employer is aware that a worker's health problems are related to certain tasks, the employer can give the worker other tasks in which these health problems are not an issue. ▪ The experts agreed that it was a good idea to **map all the current technological solutions and measures available** and to offer these as alternative options for specific problems on farms. They believed that it would be important to take into account farmers' knowledge of work processes and to make sure that these solutions are suitable in practice. One possible solution they mentioned was the automation of work processes and separating workers from areas and/or tasks with high exposure to organic dust, for instance by letting a catch-robot clear a shed full of chickens. ▪ The French experts discussed organisational measures, such as whether or not **signage** could be made uniform and be more easily recognised by their targets through better tailored messages. Not all hazards and risks can be signposted, and people respond to signs differently. Some might ignore warning signs that they do not recognise completely, while others, for example firefighters, might decide that an area is not to be entered without confirmation from authorities. The need is to ensure that viruses do not spread while keeping professional environments workable. ▪ The German experts mainly discussed **hygiene recommendations** that could improve occupational safety and protection from biological agents on farms. Their recommendations included separating living

Type of risk	Sector	Policy measure suggested by experts
		areas from occupational areas, changing clothes after work, and cleaning without dust or aerosol formation. ▪ The experts suggested **taking into account a combination of organisational, technological and human factors when looking for/developing (technical) solutions**, as these are considered equally important for the success of an intervention. One of the experts gave an example of this approach in practice by describing a successful intervention with regard to solving a problem of laboratory animal allergy in a facility in which this person was involved. The problem was solved by implementing very advanced compartmentation with strict cleaning and clothing regimes and good ventilation, with the same rules applying to both personnel and visitors. ▪ The Dutch experts mentioned two recommendations regarding OSH prevention: (1) setting strict rules for the use of PPE and (2) implementing general (universal) policy measures with a clear set of rules that apply to everyone working in or visiting the laboratory animal facility in the organisation. ▪ On this topic, one expert preferred **motivating workers to protect themselves** over top-down action. According to this expert, the crucial question is not whether the protective gear provided is individual or collective, but whether or not workers are motivated to use the gear. To address this, the expert considered it necessary to inform the parties in need of protection and include them early on in the objective-setting process. ▪
Current	Animal-related occupations/ Farming	**<u>Training and information</u>**: ▪ In general, the experts stated that it would be ideal if OSH rules applied to agriculture in the same way that they apply to other industries. Therefore, as an important first step, it would be necessary to **inform and educate farmers on regulations and rules in a clear, understandable and practical way**. The experts mentioned that farmers especially need more information on how to avoid exposure, reduce dust and endotoxin concentrations, and increase the use of PPE. An important second step would be to change **the way in which farmers work**. The experts had a specific discussion on what they called a 'superman attitude' (meaning that farmers think that they can endure a great deal) and how farmers need to adopt an attitude that involves taking better care of their own health instead. To promote this change, the experts considered *training*, with the aim of helping farmers to find and experience new/better ways of doing things and consider these helpful, especially among older generations. A third way forward would include making testing equipment available, free of charge. Lastly, the experts highlighted the

Type of risk	Sector	Policy measure suggested by experts
		importance of **information and education**, especially for foreign workers, as they may be unaware of the risks and do not understand the rules on OSH. ▪ Experts advised that farmers should learn to perform **risk assessments** (for every work location and every work task) and implement **improvements** (e.g. dust exposure, control of dust exposure) based on these risk assessments. ▪ Specifically in terms of **zoonotic risks**, one expert called for '**information' to be provided in a practical, pragmatic and dispassionate manner (in reference to vector-borne diseases)**. According to this expert, the challenge is formulating very simple messages that can be shared, enabling people to stay level-headed, feel more secure in their knowledge and adjust their behaviour accordingly. By keeping the facts straight and preventing fantasy from taking over, much more can be done in terms of collective and individual prevention.
Current	Animal-related occupations/ Farming	**Awareness-raising**: ▪ The Finnish experts mentioned two ways of raising awareness: (1) through **information and research studies** brought about by the joint efforts of the Farmers Insurance Institution, LE/Natural Resources Institute Finland, TTS/Research, Development and Training Institute and the Farmers' Occupational Health Unit at FIOH; and (2) via **vocational schools and press releases** on specific topics. ▪ The experts noted that the level of **awareness of 'sneaky' processes** that cannot be easily detected or correlated with negative health effects should be increased. They elaborated that developing chronic respiratory diseases or zoonotic diseases, although less obvious to farmers than severe work accidents, should also be taken into account in safety procedures. PPE is often refused, possibly because of this lack of awareness. ▪ The experts stressed the importance of 'thoroughness' in establishing measures for working with laboratory animals, for which commitment from all concerned is crucial. For this commitment, they recommended addressing the motivation of workers to implement interventions.
Current	Animal-related occupations/ Farming	**Regulation and policy planning**: ▪ The Danish experts declared that **clear maximum OEL values** are needed for exposure to endotoxin. An OEL would ultimately lead to the control of exposure on farms and would make it possible to implement financial penalties or fines. Experts believed that this would 'inspire' the implementation of

Type of risk	Sector	Policy measure suggested by experts
		rules and regulations and the use of protection. At the end of the discussion, the experts concluded that the policy measures taken should be a mixture of information, education and control. ▪ Because foreign workers tend to be less informed of the risks of exposure to biological agents such as organic dust, the experts envisaged that it should be a **job requirement** for foreign workers to learn about how to control exposure before they start their work. Another 'regulation' could be a demand for **production conditions** that help to improve the work environment.
Current	Animal-related occupations/ Farming	**Other — development of a risk assessment tool**: ▪ The Dutch experts suggested the development of a risk assessment tool that could be used to assess all tasks, obtain an overview of possible risks and address these risks with solutions. The experts suggested the blueprint for an RI&E for biological agents, which is currently used in the meat industry, as well as guidance on allergens, as developed by NECORD (www.nkal.nl/tools.asp). These are good examples/best practices of the tools available for performing a risk assessment aimed at biological agents. **Other — research**: ▪ The German experts had already mentioned the need **for research on limit values and causality between agents and developing adverse health effects**. They agreed with the Danish experts on this aspect. ▪ The experts mentioned a research project for which farmers were asked to test different types of respiratory protective equipment (masks). The farmers were able to wear the masks and experience for themselves the difference between wearing a mask and not wearing a mask. The difference they noticed (i.e. no coughing at home after wearing a mask at work) was the reason why they kept using these masks after the research project had ended.
Current	Animal-related occupations/ Farming	**Financial help**: ▪ According to the experts, **financial help** from the government for farmers would make it possible to improve the work environment.

Type of risk	Sector	Policy measure suggested by experts
Current	Animal-related occupations/ Farming	**Health surveillance**: ▪ In relation to health surveillance, the experts suggested screening (future) workers for existing allergies or health problems, preferably before employment commences, as is done in the triage method for sensitisation developed for and applied to bakery workers.
Emerging	Animal-related occupations/ Farming	**OSH prevention**: ▪ Occupational health services should focus more on **implementing the preventive measures** in practice. According to the experts, the usage of PPE is low among farmers; this is partly because they are entrepreneurs and therefore have to acquire PPE, such as respirators, themselves, which they consider to be expensive. The experts stated that PPE usage has already improved a little among the younger, more educated generation of farmers. ▪ An expert mentioned that **cooperation between breeders and veterinarians** could lead to developing strategies for new ways of caring for animals without using antibiotics. It was noted that breeders are professionals who do not prescribe their own medicines but who are able to obtain products at the EU level that are not available in France. Second, some experts asked for **models for calculating risks** as part of business models, although other experts considered it dangerous to connect risk prevention and cost analysis.
Emerging	Animal-related occupations/ Farming	**Training and information**: ▪ The experts saw a need for better information, education and training for people working in the agricultural sector and for farmers, to reduce the use of antibiotics for animals. ▪ The French experts talked about **educating farmers on risk prevention**. This could be done for new generations of farmers, early on in their school curriculum. The experts considered it more difficult to reach farmers at their companies, and, although training in practice would probably be the best learning option for farmers, it would probably be more realistic to provide e-training on risk prevention. ▪ The Finnish experts recommended **personal counselling with and guidance** from healthcare professionals for farmers on recognising multi-resistant agents and (alternative) treatments.

Type of risk	Sector	Policy measure suggested by experts
Emerging	Animal-related occupations/ Farming	**Awareness-raising**: ▪ The experts talked about raising awareness among consumers of the risk of multi-resistant bacteria due to the use of antibiotics when animals are bred in high concentrations. If consumers were willing to pay higher prices for meat, farmers would probably change the conditions in which they keep their animals. ▪ On the subject of awareness-raising, the experts listed three policy measures for three different target groups. First, **farmers** should be made aware of alternative strategies to using antibiotics for their animals. Second, **workers in animal transport and farmers** who own these animals should be made aware, in advance, of preventive measures that they can use to prevent biological agents from spreading during the journey, such as disinfecting the truck directly after the journey. Explaining that health-related risks are connected to financial risks can motivate them. Third, raising awareness among **the public** of how animal health and human health are connected (the importance of preventing multi-resistance, reducing the use of antibiotics, and understanding zoonoses and infection by zoonotic vectors) could pressure farmers into changing the way they breed their animals and searching for alternative methods to using antibiotics. ▪ On this topic, the experts discussed providing **information for farmers** to make them aware that they should **inform physicians** about their work when they need medical help themselves. Farmers should emphasise to physicians that their work with animals entails the usage of antibiotics and thus possibly causes the presence of multi-resistant bacteria.
Emerging	Animal-related occupations/ Farming	**Regulation and policy planning**: ▪ To reduce the use of antibiotics in animal farming, the experts proposed more rules and regulations. However, they wondered what the local effect of stricter rules and regulations would be if it continued to be possible to produce animal products in a cheap way for other countries without these restrictions. ▪ Regarding the **new legislation on the utilisation of antibiotics**, the experts questioned whether this should be part of occupational safety legislation or part of veterinary medicine legislation, and whether it is an issue of biological agents or dangerous materials.
Emerging	Animal-related occupations/ Farming	**Health surveillance**: ▪ The experts recommended health checks for farmers for multi-resistant bacteria such as MRSA.

Type of risk	Sector	Policy measure suggested by experts
Emerging	Animal-related occupations/ Farming	**Monitoring and inspection**: ▪ Within this category, the experts mentioned **research (collecting occupational hygiene samples), monitoring and performing risk assessments** on farms. All this will become easier to realise, because agricultural companies are increasing in size and decreasing in numbers. ▪ On the topic of asthma, the experts wondered about the work-related occurrence of this condition among workers in animal-related occupations such as animal farming. It was agreed that this should be **monitored and registered** to learn more about the causes, although they saw this as a difficult task, because vague health complaints are not interpreted as occupational diseases. Therefore, the experts concluded that the sector could search for the occurrence of work-related health problems such as asthma.
Emerging	Animal-related occupations/ Farming	**Financing**: ▪ Subsidies in agriculture could be dependent on both production and quality, as well as **worker welfare**.
Emerging	Animal-related occupations/ Farming	**Other — design of technological solutions**: ▪ The experts made it clear that, to reduce the risk of exposure to multi-resistant bacteria, **trends in production, changing breeding techniques and worker welfare** (including preventive measures against exposure to biological risks) should be taken into account **when building agricultural facilities**, through ergonomics and design. As an example, good ventilation was mentioned. **Other — technological innovation**: ▪ In relation to industrialised activities, a possible solution for reducing exposure for workers performing specialised tasks would be, for instance, the automation of certain (high-risk) processes, but this would require investment, which is not always realistic for small companies.
Current	Waste management	**OSH prevention**: ▪ The experts were in agreement that **prevention methods should not have targets that are too stringent**. This can even be dangerous. Even within a risk category such as biological risk, agents tend to mix, as chemical, biological and physical risks blend in real life. Ideally, a measure should protect against all risks; for example, gloves protect workers from biological, chemical and mechanical risks.

Type of risk	Sector	Policy measure suggested by experts
		They elaborated that it is difficult to determine which risks are present in a particular work situation (for example among workers in a sewage system). For chemical risks, evaluated assessment methods are available, as they are for vibration and radiation; however, for biological risks, no concrete assessment method exists. ▪ Immunisation. ▪ The Dutch experts mentioned two extra measures: (1) **vaccinations** and (2) **solutions developed using a chain approach**. As regards the second measure, they further elaborated that, because it is not possible to control how people dispose of their waste at home, it is best to think of solutions for the whole chain. An example with regard to accidents with needles was given: apothecaries should inform consumers buying needles about how to dispose of these needles without posing a risk to both themselves and waste treatment workers.
Current	Waste management	**Training and information**: ▪ The experts advised that providing training on waste materials for workers would help them to be aware of the risks that are linked to the materials they work with. ▪ In relation to this category, the experts had three suggestions for improvement: (1) providing broad training on the risks of exposure to biological pathogenic agents for members of committees on health, safety and working conditions (CHSCT; (2) providing highly specialised training for workers so that they know what type of risk they are facing when handling a specific waste source; and (3) improving information and training for temporary or external staff, hired via subcontracting companies. For these first two types of training, it was advised that hygiene in the workplace be emphasised. The experts pointed out that the waste treatment sector is not up to date in terms of hygiene regulations, especially compared with the agro-food sector. For example, one expert described waste treatment plants as boxes in which workers are 'boxed in', causing concentrations of agents to build up on their clothes and making them a risk of contamination themselves when they leave work to go home. The third type of training was suggested in particular because temporary or external workers are difficult to inform directly and are therefore often not informed of risks in the workplace. Employing uninformed workers leads to increased risks of workers being accidentally exposed. ▪ The German experts added two recommendations. First, **education of specialists for occupational safety should focus more on biological agents**, alongside technical safety. Second, they explained the training and information are generally aimed at occupational safety specialists, industrial physicians

Type of risk	Sector	Policy measure suggested by experts
		or employers. Although these individuals are supposed to inform the workers, the workers still seem to be ill informed. They considered the complexity of laws, decrees or technical rules to be the problem and therefore came up with the following solution: create **short briefing cards** that contain only a single topic and some figures, to simplify the instructions for workers.
Current	Waste management	**Regulation and policy planning**: ▪ According to the experts, the waste industry as a whole needs more attention from researchers and policy-makers with the purpose of establishing (1) clear maximum limits of concentration of biological agents (maximum permissible values), and (2) better and more clearly written rules and regulations. No vague rules such as 'suitable concentration' should be established, because these do not clarify what the rules mean in practice. ▪ The experts explained that **prohibition** (i.e. no longer allowing certain types of waste are in residential waste or stricter rules for waste separation by consumers) is effective only in the long run within their sector. This is related to the facts that sources of waste are often unknown and people still have certain waste at home. Solutions should therefore focus more on **technological measures** and less on regulations.
Current	Waste management	**Monitoring and inspection**: ▪ Prohibitions would be useful, as the experts believed that consequences/sanctions were necessary for the implementation of preventive measures. This will be possible when researchers and policy-makers set clear regulations and maximum permissible values, as mentioned earlier in the report. ▪ The experts talked about how waste handling is licensed in Finland and strictly monitored, but **legislation and control of plants and their operations** can still be improved, including health inspections. Currently, waste treatment plants must execute a thorough environmental impact assessment, which includes a risk assessment of the work environment. ▪ The experts claimed that there was a problem with the **degree of supervision, the attention paid to usage of preventive measures and the obligations to monitor this**. Additional measures should address this lack of in-company monitoring. ▪ In this regard, the experts stated that the **monitoring of PPE usage** within companies should be **uniform**. Currently, every company decides itself how to deal with workers refusing to use PPE (gloves, long sleeves, respiratory equipment). The sector should decide together how to monitor and use

Type of risk	Sector	Policy measure suggested by experts
		sanctions when rules are not followed. In addition, the experts recommended **research-based, tailor-made preventive programmes and information**. As regards this preventive measure, it was explained that it is possible to create tailor-made preventive programmes and information only after making an effort to **study which agents are present in the air of waste treatment plants**, which constitutes a risk to workers in the meantime.
Current	Waste management	**Other — developing technological solutions** (to prevent or limit exposure) and research: ▪ Separating workers from waste: the Finnish experts recommended **separating workers from waste** completely, as has already been done in several new waste treatment plants in Finland. ▪ The French experts elaborated thoroughly on the subject of **developing technological solutions**. They pointed out two areas in need of attention while developing technological solutions. First, a tremendous amount of existing knowledge on preventing biological risks is unused today, because it is either ignored or even dismissed (by those responsible for prevention). However, it should be taken into account in the early stages of the **development of equipment**. Second, very little attention is paid to either the production stage or **primary prevention through technological design solutions**, even though the Labour Code gives priority to collective protection over individual protection (tertiary prevention: PPE). Lastly, regarding research, the experts agreed that the traceability of and long-term exposure to biological agents need to be researched in relation to, for example, cancer prevention. ▪ According to the experts, technological innovations (robots) could offer important solutions, such as separating workers from waste, as was done in green waste processing (in this case, this was done in consideration of the environment). Innovations are time-consuming, and, in order to be of interest within the sector of waste treatment, innovations should be economically profitable in the end. For instance, using a robot would mean no longer having to pay workers
Current	Waste management	**Awareness-raising**: ▪ To raise awareness of risks in waste treatment among new workers, the experts thought it a good idea to offer an introduction course to workers when they first start their job, such as in hospitals.
Emerging	Waste treatment	**OSH prevention**: ▪ The French experts recommended two measures in this category: (1) **separating activities in waste treatment plants** (e.g. selection and scrubbing) to prevent exposure to different waste flows in the

Type of risk	Sector	Policy measure suggested by experts
		sanitation chain, and (2) **improving ventilation** to reduce dust concentration levels and as a result reduce concentration levels of biological agents in the air.
Emerging	Waste treatment	**Training and information**: ▪ For workers who are exposed to a combination of risks in the waste treatment sector, the experts recommended better information and training on the occupational risk of exposure to biological agents.
Emerging	Waste treatment	**Regulation and policy planning**: ▪ In relation to the trend in recycling resulting in more handling of waste in the (near) future, the Danish experts considered it important to **create more precise rules** to protect workers who handle waste.
Emerging	Waste treatment	**Financing**: ▪ The experts recommended **funding research** for improving knowledge of biological agents in the waste treatment sector. ▪ The experts suggested that, when companies or municipalities call for tenders, they could ask especially for waste treatment companies with sustainable management methods.
Emerging	Waste treatment	**Other — research**: ▪ The experts briefly mentioned research for establishing **a biological risk exposure matrix**. ▪ In regard to the combination of risks they mentioned, the experts recommended investigating which specific biological agents workers are exposed to, and determining which health effects are reported in relation to these exposures, to **discover the specific risks** for which control/preventive measures can be developed to prevent adverse health effects. As a downside of this recommendation, it was mentioned that this would take a considerable amount of time. **Other — technological solutions**: ▪ In relation to garbage being collected less frequently than before, the experts suggested a chain approach to **find solutions for separating waste at the source,** which is more effective, and even processing part of the waste locally (e.g. at home), for instance by using a Pharma filter (a system that makes it possible to throw out biodegradable plastic products using a cruncher connected to the local sewage system, where solid waste and wastewater get separated and water gets filtered).

Type of risk	Sector	Policy measure suggested by experts
Current	Health care	**OSH prevention**: ▪ Immunisation: the German experts mentioned two problems with regard to immunisation. First, in some cases just a few vaccines are available. Second, in Germany people are free to choose whether they are immunised or not (constitutional law; integrity of the body and data privacy). Immunisation is recommended, but workers can refuse it. They noted that the only way to maintain immunised workers is to demand **immunisation as a job requirement**. The experts concluded that, although immunisation cannot be enforced, it is still the most efficient occupational safety policy for the healthcare sector. ▪ As an additional policy measure, the experts mentioned that it would be helpful to make a list of unsafe needles and needle systems, with information on safer alternatives, and make this list publicly available for all relevant stakeholders. Furthermore, existing stocks of unsafe needle systems should be removed and destroyed, to make sure that they are no longer used.
Current	Health care	**Training and information**: ▪ According to the Danish experts, the best way forward is to introduce **targeted learning courses** (education on law, prevention and information) **for all kinds of workers**, including workers who are not involved in health care, such as cleaning personnel. ▪ The Finnish experts agreed that it would be important to introduce training on a continuous basis and to repeat instruction procedures to all workers (for example by using video instruction). ▪ The German experts pointed out that **training and information** about protective measures for dealing with the risk of exposure to biological agents in health care and raising risk awareness should **focus on workers serving as role models** (e.g. teaching/leading physicians). They illustrated their point by giving examples of physicians in hospitals not disposing of needles correctly, working with open laboratory coats and seeing these laboratory coats as a status symbol instead of PPE. Nurses seem to be more aware of protective policies. This was confirmed in the biological laboratory sector, in which most technicians were aware of the legal requirements (BioStoffV) or technical rules regarding biological agents, whereas university graduates were not. ▪ This measure was mentioned as being needed for cleaning personnel. Furthermore, training is considered an important part of a successful implementation process regarding safe needle systems.
Current	Health care	**Awareness-raising**:

Type of risk	Sector	Policy measure suggested by experts
		▪ For this purpose, the experts recommended **obligatory (e-)courses** and **targeted campaigns**. ▪ In addition, and in line with the first policy example, the experts agreed that it would be important to **increase the awareness of workers by offering information, instruction and guidance**. ▪ This measure was also mentioned as needed for cleaning personnel.
Current	Health care	**Regulation and policy planning**: ▪ The experts mentioned that **follow-up and sanctions are necessary** to solve problems with biological risks in health care. ▪ The Finnish experts talked about the challenge of **notifying authorities or the National Institute for Health and Welfare in time** about exposures or (suspected) occupational diseases. Sometimes it takes a few years, or the National Institute for Health and Welfare is not informed at all, which according to the experts hinders preventive action. The experts agreed that diseases classified as generally dangerous should be reported immediately. They reported three factors hindering adequate reporting: (1) both authorities and the National Institute for Health and Welfare need to be notified, yet one notification should be sufficient; (2) quick reporting is hindered by both healthcare privacy requirements and the Act of Data Protection in Finland; and (3) not every person who is ill as a consequence of exposure to biological agents reports their illness, so it may remain unknown. The experts mentioned the additional significant barrier of a patient being able to withhold permission to inform their employer of any health problems. ▪ The Dutch experts mentioned that, at the national level in the Netherlands, a great deal is regulated by means of the 'Arbocatalogus'. However, the question remains to what extent the measures prescribed in the 'Arbocatalogus' are actually implemented in practice. In addition, it was mentioned that policy at a European level is considered necessary, in addition to regulations at national levels. For instance, prescribing that it is mandatory to use safe needle systems and that old needle systems need to be destroyed may not be enough of an incentive for suppliers/producers to develop safe needle systems and/or make them available, since the Dutch market is considered too small. However, these producers/suppliers would probably become more active if the use of safe needle systems were mandatory in the EU as a whole.
Current	Health care	**Financing**:

Type of risk	Sector	Policy measure suggested by experts
		▪ Preparing for exceptional conditions is challenging, but all experts agreed on the need for **a contingency plan**. According to the experts, no money (at the national level) is reserved for exceptional conditions, such as protecting workers from Ebola. In health care, the financing of biological risk assessment is managed through general administration. Exceptional conditions can also affect or even originate from other sectors, such as animal-related occupations and waste treatment. For instance, a disease may originate from cattle, and these cattle may then have to be slaughtered and disposed of by waste workers. Therefore, a contingency plan, **with accompanying finances**, for protecting workers against the risks of exceptional outbreaks is needed for these sectors. ▪ The experts concluded that the usage of safe needle systems would need to be financed, possibly by return of costs from health insurance companies. Furthermore, financing is considered an important part of a successful implementation process for safe needle systems.
Current	Health care	**Other — development process with producers**: ▪ The experts concluded that it is important to bring producers into the development process, and possibly also provide funding for the development of safe needle systems for all situations, while taking into account user scenarios and other possible risks.
Emerging	Health care	**OSH prevention**: ▪ The experts considered preventive measures to be dependent on how people adapt them (the human factor). They concluded that whether or not workers live by the instructions must be **monitored** and that neglect must be addressed. ▪ In relation to OSH prevention of agents with antibiotic resistance, three measures were suggested: (1) ensuring the **sufficiency of isolation/quarantine premises**, including in older hospitals; (2) carrying out **immunisation and information campaigns on vaccination**, with correct and suitable information for the public to prevent false information; and (3) paying **attention to the admittance of visitors** — relatives are welcome to visit patients, but they may pose a risk of bringing diseases (e.g. multi-resistant bacteria) into the hospital. ▪ An expert called for a 'balanced' information **campaign on public health policies,** such as vaccines and medicines, with information from scientists, so that the public is able to make well-informed decisions. ▪ PPE was mentioned.

Type of risk	Sector	Policy measure suggested by experts
Emerging	Health care	**Training and information**: ▪ The experts recommended better **training and information** for healthcare workers. ▪ The Finnish experts recommended (1) **information from and counselling with occupational health service providers** and (2) **repeated training and instructions** on protective measures such as PPE and hand hygiene. The experts agreed instructions should be followed at all times, with no exceptions. ▪ In relation to training and information on agents with antibiotic resistance, one French expert suggested two measures: (1) **advocating best practices for prescribing antibiotics with physicians**, and (2) **improving the understanding of hygiene among all healthcare workers**, such as nurses, in-home assistants and healthcare providers. ▪ The experts agreed that all workers in health care should be **informed about how to deal with the risk of increased occurrence of biological agents of higher risk groups**. Workers in smaller hospitals and in outpatient medical care should be included. ▪ In relation to preventing agents from becoming multi-resistant, it would be useful for physicians to have **an overview of which antibiotics can be used or should not be used** in a specific (work-related) situation.
Emerging	Health care	**Regulation and policy planning**: ▪ The experts recommended developing **emergency plans** for pandemic situations. ▪ In addition to this overview, the Dutch experts considered it necessary to formulate clear policy measures that are aimed at reducing the use/prescription of antibiotics, as this is still very common in current protocols that are used in cases of infection. They recommended checking the current guidelines for prescribing antibiotics, to be able to resolve this issue at the source, and whether or not this issue is taken into account when new guidelines are developed. In addition, when setting regulations, **how waste is handled** should also be taken into account, to prevent antibiotics being further distributed into the environment. Furthermore, the experts indicated that **national rules and regulations** should be compared with **EU rules and regulations** on this topic, and that they should be aligned, and wondered if this was the case.
Emerging	Health care	**Financing**:

Type of risk	Sector	Policy measure suggested by experts
		▪ **Financing or subsidies** should be made available to support smaller hospitals and outpatient medical care facilities in purchasing PPE for workers so that they can be protected in cases of biological agents of higher risk groups.

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The European Agency for Safety and Health at Work (EU-OSHA) contributes to making Europe a safer, healthier and more productive place to work. The Agency researches, develops, and distributes reliable, balanced, and impartial safety and health information and organises pan-European awareness raising campaigns. Set up by the European Union in 1994 and based in Bilbao, Spain, the Agency brings together representatives from the European Commission, Member State governments, employers' and workers' organisations, as well as leading experts in each of the EU Member States and beyond.

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