EXPOSURE TO BIOLOGICAL AGENTS AND RELATED HEALTH PROBLEMS IN ANIMAL-RELATED OCCUPATIONS

Health effects related to exposure to biological agents in the workplace

Between 2015 and 2017, the European Agency for Safety and Health at Work (EU-OSHA) carried out a project to address the lack of knowledge on and awareness of exposures to biological agents and the related health problems, as well as the lack of a systematic approach to workplace prevention in terms of these risk factors. In 2016, an extensive literature review was carried out on work-related diseases due to biological agents. The research confirmed that people in animal-related occupations are at a high risk of being exposed to biological agents. In addition to the literature review, an expert survey and the collection of data on health problems and exposures from monitoring systems, information on policy measures intended to reduce the risks posed by biological agents was gathered through interviews with experts and focus groups with workplace practitioners. The results were discussed and additional information was obtained at a stakeholder workshop in 2017.

This article provides information on a broad spectrum of health problems associated with animal-related occupations. In addition to livestock farming, in which workers (including famers) breed, care for and/or handle animals, the article also covers abattoir and slaughterhouse workers, veterinarians, animal workers in laboratories and zoo personnel. Some of these occupations, on which a considerable amount of information was gathered during the scientific literature review, are addressed more specifically and a wide variety of biological agents and related diseases are highlighted. Table 1 and Table 2 present an overview of diseases that occur in this group of occupations.

Infectious diseases

- **Abattoir and slaughterhouse workers**

Abattoir workers are exposed to biological agents primarily through direct contact with infected animals, their blood and/or body fluids or their tissues. However, infections can also be transmitted by vectors ([1]), for example ticks, flies or mosquitoes.

Among abattoir and slaughterhouse workers, including meat inspectors and meat salvagers, the bacteria that lead to frequently reported infections are *Leptospira* spp., *Brucella* spp., *Coxiella burnetii* and bovine tubercle bacilli (*Mycobacterium bovis*) (Canini, 2010; Ganter, 2015; Haagsma et al., 2012; McDaniel et al., 2014), leading to leptospirosis, brucellosis, Q fever and tuberculosis. Among abattoir workers, bird-related zoonoses and their bacteria-related diseases are ornithosis, salmonellosis, campylobacteriosis, yersiniosis, colibacteriosis, erysipeloid and listeriosis (Kozdruń, Czekaj and Stys, 2015).

Slaughterhouse workers are also at risk of catching avian influenza and influenza-like illnesses caused by louping ill virus (EU-OSHA, 2007; Haagsma et al., 2012; Jeffries et al., 2014), West Nile virus infection and Newcastle disease, and the hepatitis B and E viruses (Haagsma et al., 2012; Pavio and Mansuy, 2010). Fungal infections may result in histoplasmosis and cryptococcosis.

In addition, tick-borne diseases are of concern to these workers, (e.g. Q-fever, tularaemia, Lyme borreliosis, encephalitis, Russian spring-summer encephalitis and Crimean Congo haemorrhagic fever) (Kozdruń, Czekaj and Stys, 2015) as workers can be infected via the blood, body fluids and tissues of infected animals (Bente et al., 2013). Crimean Congo haemorrhagic fever, a vector-borne disease transmitted by *Hyalomma* ticks, is endemic among slaughterhouse workers in Africa, the Balkans, the Middle East and Asia. The occurrence of Crimean Congo haemorrhagic fever in Europe, notably in

([1]) Vector: an organism that does not cause disease itself but that spreads infection by conveying pathogens from one host to another. Infection transfer may be the result of bites or other direct animal contact, or from bites by vectors (e.g. tick-borne diseases).

Spain and Portugal, has also been confirmed by the presence of the *Hyalomma* tick in these countries, together with virological or serological evidence, indicating a wider spread of the disease.

- **Livestock farming**

People who work with livestock may be exposed to animal hair and dander, animal fluids (blood, urine, milk, etc.), animal feed, animal-related parasites and microorganisms found in these sources. The variety of activities involved in agricultural work and the consequential exposure of workers to a diverse range of biological agents results in the prevalence of various work-related diseases in this sector. These range from outbreaks of infectious diseases such as zoonoses (e.g. Q-fever) to the health problems resulting from the inhalation of organic dust: annual lung function decline, organic dust toxic syndrome (COPD) and respiratory disease with lower forced expiratory volume.

Bacterial infections that occur frequently in farming are leptospirosis, Q-fever and tuberculosis (Adler and de la Peña Moctezuma, 2010; Dorko, Rimárová and Pilipčinec, 2012; Dutkiewicz et al., 2011; Ganter, 2015; Haagsma et al., 2012; Honarmand, 2012; Morrissey, Cotton and Ball, 2014). The major exposure route for animal farmers resulting in infections is through the inhalation of aerosols from urine, faeces and birth by-products. Furthermore, exposure to meticillin-resistant *Staphylococcus aureus* (MRSA) is a bacterial risk of concern (Doyle, Hartmann and Lee Wong, 2012; EU-OSHA, 2007; Guardabassi et al., 2013; Montano, 2014; Stefani et al., 2012). It is an issue in pig farming in particular, as MRSA can be transferred from pigs to humans.

In the agricultural context, the virus infections that are referred to the most are hepatitis E among pig farmers (De Schryver et al., 2015; Dungan, 2010; Haagsma et al., 2012; Lewis, Wichmann and Duizer, 2010; Pavio and Mansuy, 2010; Sayed et al., 2015; Wilhelm et al., 2011;) and swine and avian influenza among pig and poultry farmers (Dungan, 2010; Dutkiewicz et al., 2011; EU-OSHA, 2009; Gangurde et al., 2011; Haagsma et al., 2012; Jeffries et al., 2014; Kozdruń, Czekaj and Stys, 2015; Trajman and Menzies, 2010).

Storage facilities on farms may also be infested by animals that carry viruses. An example is the bank vole, a rodent that may cause the disease nephropathia epidemica or epidemic nephropathy, a recognised occupational disease in the farming sector of some countries. This is a type of viral haemorrhagic fever with renal syndrome caused by the Puumala virus, which is found predominantly in Scandinavia and Finland, although it has also been reported elsewhere in northern Europe, Poland and Russia. The bank vole is the reservoir for the virus, which humans contract by inhaling aerosolised vole droppings.

Relatively few fungal infections in agricultural workers were identified in the reviewed literature. Onychomycosis (nail infections), sycosis (inflammation of hair follicles, especially of the beard area) and suppurating tinea kerion (fungal ringworm infection of the hair follicles of the scalp (and occasionally the beard)) are mentioned by EU-OSHA (2008) and dermatomycoses by Seyfarth and Eisner (2010).

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 noted as an emerging zoonosis by Dutkiewicz et al. (2011). No vulnerable groups were identified.

- **Pet shop workers**

Halsby et al. (2014) reviewed the zoonotic risks from pet shops. Pet shops can be the focus of very large outbreaks of disease, transmitted from animal to animal and then through several owners or visitors. Bacterial, viral and fungal diseases were identified, and ranged in severity from mild to life threatening. Salmonellosis and psittacosis were the most commonly documented diseases, however more unusual infections such as tularemia were also identified. Many related to infections in pet shop workers. The animals involved in the transmission of these infections included birds, mammals and rodents, and covered both common household pets, such as dogs and cats, and more exotic creatures, such as iguanas and prairie dogs. Some zoonotic infections were associated with a variety of different companion animals (e.g. salmonellosis), whereas others were associated with only a narrow range of species (e.g. psittacosis).

- **Veterinarians**

Veterinarians and their assistants are at increased risk of a broad spectrum of diseases, as they are frequently exposed to animals carrying (infectious) biological agents. The infection may be transferred by bites or other direct animal contact or by vector bites (e.g. tick-borne diseases). Well-known infections are caused by exposure to swine or avian influenza virus, *Brucella* spp., *Bartonella henselae*, *Campylobacter* spp., *Chlamyodphila psitacci*, *Clostridium tetani*, *Coxiella burnettii*, *Pasteurella multocida*, *Salmonella* spp., and *Toxoplasma gondii* (Haagsma et al., 2012), as well as to MRSA (Doyle, Hartmann and Lee Wong, 2012; Guardabassi et al., 2013; Haagsma et al., 2012). There are many other bacteria-, virus-, fungi- or vector-related infections (Breitschwerdt et al., 2010; Canini, 2010;; Dutkiewicz et al., 2011; Ganter, 2015; Hardin, Crandall and Stankus, 2011;;; McDaniel et al., 2014; Montano, 2014; Samadi, Wouters and Heederik, 2013; Seyfarth and Eisner, 2010; Stewardson and Grayson, 2010; Wang, Chang and Riley, 2010[2].).

Increased risks are reported due to climate change because the geographical range of certain biological agents is expanding. This was reported for the agents causing Rift Valley fever, yellow fever, malaria, dengue fever and chikungunya (Applebaum et al., 2016). Moreover, an increasing number of Bartonella species have been identified as zoonotic pathogens, transmitted by animal bites and scratches, arthropods and even needlestick injuries (Breitschwerdt et al., 2010). Infections due to the fungus *Sporothrix schenckii* (inducing sporotrichosis) in veterinarians is reported as a new risk category, as zoonotic transmission has been described in isolated cases or in small outbreaks (Barros et al., 2011).

Zoonotic diseases account for up to 30 % of cases of occupational illnesses reported in zoos in India among zoo and wildlife veterinarians (Chethan Kumar et al., 2013), and, although the situation in India may be different, because of worldwide breeding programmes, veterinarians in European zoos may also be exposed to exotic biological agents.

- **Overview of infectious agents**

An overview of the biological agents and related infectious diseases in animal-related occupations is presented in Table 1. For some biological agents, the potential for vector transmission is indicated.

Table 1: Overview of reported occupations, biological agents (including allergenic agents) and related diseases in animal-related occupations, grouped per agent category

Agent	Occupation	Disease
Bacteria		

[2] See also EU-OSHA, 2007; EU-OSHA, 2008; EU-OSHA, 2009;Dorko, Rimárová and Pilipčinec, 2012; Honarmand, 2012; ; Islam et al., 2013; Jeffries et al., 2014; Kozdruń, Czekaj and Stys, 2015; Lewis, Wichmann and Duizer, 2010; Pavio and Mansuy, 2010; Sayed et al., 2015;

Agent	Occupation	Disease
Bacillus anthracis	Agriculture (animal worker: breeder, cattle worker, livestock handler, livestock farmer) Animal worker (handler) Butcher Veterinarian Zoo personnel	Anthrax
Bartonella henselae	Abattoir worker Agriculture (animal worker/breeder) Animal worker (carer, handler) Pet (shop) worker Veterinarian	Bartonellosis Cat-scratch disease
Borrelia burgdorferi	Abattoir worker (including poultry) Agriculture (animal worker: breeder, cattle worker, livestock handler, poultry farmer) Animal worker (carer, handler) Veterinarian Zoo personnel	Lyme borreliosis
Brucella spp.	Abattoir worker Agriculture (animal worker: breeder, cattle worker, livestock handler, livestock farmer) Animal worker (handler) Butcher Veterinarian Zoo personnel	Brucellosis
Brucella (abortus, ovis, melitensis, suis, canis) Brucella antigen	Veterinarian	Brucellosis
Campylobacter spp.	Abattoir worker Abattoir worker (poultry) Agriculture (animal worker: breeder of ornamental birds, cattle worker, livestock handler, livestock farmer, poultry farmer, handler) Butcher Veterinarian	*Campylobacter* infection Campylobacteriosis

Agent	Occupation	Disease
	Zoo personnel	
Chlamydophila psittaci	Abattoir worker Abattoir worker (poultry) Agriculture (animal worker: breeder of ornamental birds, breeder, poultry farmer) Animal worker (birds) Animal worker (carer, handler) Butcher Pet (shop) worker Veterinarian Zoo personnel	Chlamydiosis Ornithosis Psittacosis Chlamydial diseases Melioidosis
Corynebacterium pseudotuberculosis	Butcher Veterinarian	Caseous lymphadenitis
Coxiella burnetii (may be vector transmitted)	Abattoir worker Abattoir worker (poultry) Agriculture (animal worker: breeder, cattle worker, livestock handler, livestock farmer, poultry farmer) Animal worker (contact with live or dead animals, animal secretions) Animal worker (handler, trader) Butcher Pet (shop) worker Veterinarian	Q-fever
Erysipelothrix rhusiopathiae	Abattoir worker Abattoir worker (poultry) Agriculture (animal worker: breeder ornamental birds, breeder, poultry farmer) Animal worker (handler) Butcher Veterinarian Zoo personnel	Erysipeloid
Escherichia coli	Abattoir worker (poultry) Agriculture (animal worker: breeder ornamental birds, poultry farmer)	Colibacteriosis Colibacillosis

Agent	Occupation	Disease
	Veterinarian Zoo personnel	
Francisella tularensis (may be vector transmitted)	Agriculture (animal worker/breeder, handler, trader) Animal worker (contact with live or dead animals, animal secretions) Pet (shop) worker Veterinarian Zoo personnel	Tularaemia
Legionella spp.	Agriculture (animal worker/breeder) Animal worker (contact with live or dead animals, animal secretions) Animal worker (trader) Pet (shop) worker Veterinarian Zoo personnel	Legionellosis
Leptospira ssp. (may be vector-transmitted)	Abattoir worker Agriculture (animal worker: breeder, cattle worker, livestock handler, livestock farmer) Animal worker (carer, handler) Butcher Pet (shop) worker Veterinarian	Leptospirosis
Leptospira hardjo, pomona	Abattoir worker	Leptospirosis
Listeria monocytogenes	Abattoir worker (poultry) Agriculture (animal worker: breeder ornamental birds, cattle worker, livestock handler, livestock farmer, poultry farmer) Butcher Veterinarian Zoo personnel	Listeriosis
Pyrogenic germs	Abattoir worker Agriculture (animal worker/breeder) Animal worker (handler)	

Agent	Occupation	Disease
	Veterinarian	
Meticillin-resistant *Staphylococcus aureus* (MRSA)	Livestock farmer Veterinarian	
Mycobacterium marinum	Abattoir worker Agriculture (animal worker/breeder) Animal worker (handler)	Tuberculosis
Mycobacterium tuberculosis	Abattoir worker Agriculture (animal worker/poultry and pig farmer)	Tuberculosis
Mycobacterium tuberculosis, bovis	Abattoir worker Agriculture (animal worker: breeder, livestock farmer) Animal worker (handler)	Tuberculosis
Mycobacterium tuberculosis, bovis, caprae	Agriculture (animal worker/breeder) Animal worker (contact with live or dead animals, animal secretions) Animal worker (trader) Butcher Pet (shop) worker Veterinarian Zoo personnel	Tuberculosis
Pasteurella spp.	Abattoir worker Agriculture (animal worker/breeder) Veterinarian	
Pasteurella multocida	Abattoir worker Agriculture (animal worker/breeder) Animal worker (handler) Veterinarian	
Salmonella spp. (may be vector transmitted)	Abattoir worker Abattoir worker (poultry) Agriculture (animal worker: breeder ornamental birds, breeder, livestock farmer, poultry farmer) Butcher	Salmonellosis

Agent	Occupation	Disease
	Pet (shop) worker Veterinarian Zoo personnel	
Staphylococcus aureus spp.	Abattoir worker Agriculture (animal worker/cattle worker, livestock handler) Butcher Veterinarian	
Streptococcus spp.	Agriculture (animal worker/cattle worker, livestock handler) Veterinarian	
Streptococcus pyogenes	Abattoir worker	
Streptococcus suis	Agriculture (animal worker/pig farmer)	Meningitis
Yersinia	Abattoir worker (poultry) Agriculture (animal worker: breeder ornamental birds, poultry farmer) Veterinarian Zoo personnel	Yersiniosis
Fungi		
Dermatophytes	Abattoir worker Agriculture (animal worker/breeder) Veterinarian	Dermatomycoses
Acremonium sp.	Veterinarian	Dermatomycoses
Basidiobulus ranarum	Veterinarian	Dermatomycoses
Black fungi (pathogen of Chromoblastomycosis)	Veterinarian	Dermatomycoses Chromoblastomycosis
Coccidioides immitis, posadasii	Veterinarian Zoo personnel	Coccidiosis Coccidioidomycosis
Conidiobolus sp.	Veterinarian	Dermatomycoses
Cryptococcus	Abattoir worker (poultry) Agriculture (animal worker/poultry farmer) Veterinarian	Cryptococcosis

Agent	Occupation	Disease
	Zoo personnel	
Epidermophyton	Abattoir worker Agriculture (animal worker/breeder)	Tinea
Fusarium sp.	Veterinarian	Dermatomycoses
Histoplasma capsulatum	Abattoir worker (poultry) Agriculture (animal worker/poultry farmer) Veterinarian Zoo personnel	Histoplasmosis
Lacazia loboi	Veterinarian	Dermatomycoses
Madurella mycetomatis	Veterinarian	Dermatomycoses
Phialophora verrucosa	Driver (professional)	Chromomycosis
Pseudallescheria boydii	Veterinarian	Dermatomycoses
Microsporum spp.	Abattoir worker Butcher Pet (shop) worker Veterinarian	Dermatomycoses Ringworm
Microsporum canis	Veterinarian	Dermatomycoses
Scedosporium spp.	Veterinarian	Dermatomycoses
Sporothrix schenckii	Veterinarian	Dermatomycoses Sporotrichosis
Zoophilic dermatophytes	Agriculture (animal worker/livestock farmer) Animal worker (fur farms) Shepherd	Dermatomycoses
Trichophyton	Abattoir worker Agriculture (animal worker: breeder, cattle worker, livestock handler) Veterinarian	Dermatomycoses, Tinea
Trichophyton verrucosum	Shepherd	Trichophyton verrucosum infections
Zygomycota	Veterinarian	Dermatomycoses
Parasites		

Agent	Occupation	Disease
Ancylostomatidae	Veterinarian Zoo personnel	Cutaneous larva migrans
Babesia	Veterinarian Zoo personnel	Babesiosis
Babesia canis	Veterinarian	Canine babesiosis
Balantidium coli	Veterinarian Zoo personnel	Balantidiasis
Brugia malayi	Zoo personnel	Malayan filariasis
Cryptosporidium spp.	Animal worker (handler) Veterinarian Zoo personnel	Cryptosporidiosis
Dirofilaria repens	Veterinarian Zoo personnel	Dirofilariasis
Echinococcus	Abattoir worker Agriculture (animal worker/breeder) Veterinarian Zoo personnel	Echinococcosis (Hydatidosis)
Giardia lamblia	Veterinarian Zoo personnel	Giardiasis
Leishmania	Veterinarian Zoo personnel	Leishmaniasis
Plasmodium (vector-transmitted)	Zoo personnel	Malaria
Taenia	Veterinarian Zoo personnel	Coenuriasis Taeniasis
Trichinella	Veterinarian Zoo personnel	Trichinellosis
Toxocara canis	Animal worker (carer) Veterinarian	Toxocariasis
Toxocara canis, cati, Baylisascaris procyonis, Ascaris suum	Veterinarian Zoo personnel	Visceral larva migrans

Agent	Occupation	Disease
Toxoplasma gondii	Abattoir worker Animal worker (carer) Pet (shop) worker Veterinarian Zoo personnel	Toxoplasmosis
Trypanosoma	Veterinarian Zoo personnel	Trypanosomiasis
Trypanosoma cruzi	Veterinarian	Chagas disease
Prions		
Prion	Abattoir worker Agriculture (animal worker/cattle worker, livestock handler) Veterinarian	New variant Creutzfeldt-Jacob Disease
Viruses		
Aphthovirus	Veterinarian Zoo personnel	Foot-and-mouth disease
Avian influenza virus	Abattoir worker (poultry) Agriculture (animal worker: breeder ornamental birds, breeder, poultry farmer) Animal worker (contact with live or dead animals, animal secretions) Animal worker (trader) Pet (shop) worker Veterinarian Zoo personnel	Avian influenza
Influenza (H5N1, H7N1, H7N7, H1N1), coronavirus A	Agriculture (animal worker/poultry and pig farmer)	Influenza
Influenza A virus (e.g. H5N1 strain)	Abattoir worker Animal worker (birds) Pet (shop) worker Zoo personnel	Influenza type A

Agent	Occupation	Disease
Swine influenza (*Orthomyxoviridae* type A: H1N1 virus)	Agriculture (animal worker/pig farmer)	Influenza-like illness, namely, chills, fever, sore throat, muscle pains, severe headache, coughing, weakness, and general discomfort
Buffalopox virus (BPXV)	Veterinarian Zoo personnel	Buffalo pox
Chikungunya virus	Veterinarian	Chikungunya fever
Coltivirus	Veterinarian Zoo personnel	Colorado tick fever
Cowpox virus	Abattoir worker Agriculture (animal worker/breeder) Animal worker (handler) Veterinarian	Cowpox
Crimean Congo haemorrhagic fever virus	Veterinarian Zoo personnel	Crimean Congo haemorrhagic fever
Dengue virus	Abattoir worker Agriculture (animal worker/breeder) Animal worker (contact with live or dead animals, animal secretions) Animal worker (trader) Pet (shop) worker Veterinarian Zoo personnel	Dengue fever
Ebola/Marburg virus	Abattoir worker Agriculture (animal worker/breeder) Animal worker (contact with live or dead animals, animal secretions) Animal worker (trader) Pet (shop) worker Veterinarian Zoo personnel	Haemorrhagic shock, death
Arbovirus	Veterinarian Zoo personnel	Equine encephalomyelitis

Agent	Occupation	Disease
Hanta virus	Animal worker (carer) Veterinarian Zoo personnel	Hantavirus pulmonary syndrome
Hendra virus	Animal worker (handler) Veterinarian Zoo personnel	Hendra virus disease
Hepatitis A, B, C virus	Veterinarian	Hepatitis A, B, C
Hepatitis E virus	Abattoir worker Agriculture (animal worker/pig farmer) Veterinarian Zoo personnel	Hepatitis E
Herpes B, B virus	Veterinarian Zoo personnel	B-virus infection cercopithecine herpesvirus 1 (B virus disease of macaques)
Japanese encephalitis virus	Veterinarian Zoo personnel	Japanese encephalitis
Kyasanur forest disease virus	Veterinarian Zoo personnel	Kyasanur forest disease
Lassa virus	Airline personnel	Lassa fever
Louping ill virus	Abattoir worker Butcher Veterinarian Zoo personnel	Influenza-like illness
Lymphocytic choriomeningitis virus	Animal worker (handler) Veterinarian Zoo personnel	Meningitis
Lyssavirus	Abattoir worker Animal worker (handler) Butcher Veterinarian Zoo personnel	Rabies
Measles virus	Abattoir worker	Measles

Agent	Occupation	Disease
	Agriculture (animal worker/breeder) Animal worker (contact with live or dead animals, animal secretions) Animal worker (trader) Pet (shop) worker Veterinarian Zoo personnel	
Murray Valley encephalitis virus (MVEV)	Veterinarian Zoo personnel	Murray Valley encephalitis
Monkeypox virus	Animal worker (handler) Pet (shop) worker Veterinarian	Monkeypox
Papillomavirus	Abattoir worker Agriculture (animal worker/breeder) Animal worker (handler) Veterinarian	Plantar, butcher warts
Parapoxvirus	Abattoir worker Agriculture (animal worker/breeder) Animal worker (handler) Butcher Veterinarian	Contagious ecthyma Orf
RNA virus of the genus *Flavivirus*	Abattoir worker Agriculture (animal worker/breeder) Animal worker (contact with live or dead animals, animal secretions) Animal worker (trader) Pet (shop) worker Veterinarian Zoo personnel	Yellow fever
Simian foamy virus	Animal worker (carer)	//
Simian parvovirus	Animal worker (carer)	//
Simian type D retrovirus	Animal worker (carer)	//

Agent	Occupation	Disease
Saint Louis encephalitis virus	Veterinarian Zoo personnel	Saint Louis encephalitis
Tick-borne encephalitis virus	Abattoir worker (poultry) Agriculture (animal worker/poultry farmer) Veterinarian Zoo personnel	Encephalitis Russian spring-summer encephalitis
SARS coronavirus	Abattoir worker Agriculture (animal worker/breeder) Animal worker (contact with live or dead animals, animal secretions) Animal worker (trader) Pet (shop) worker Veterinarian Zoo personnel	Severe acute respiratory syndrome (SARS)
Tanapox virus	Veterinarian Zoo personnel	Tanapox
Vesicular stomatitis Indiana virus	Abattoir worker Butcher Veterinarian	Vesicular stomatitis
	Veterinarian Zoo personnel	Viral haemorrhagic fevers
West Nile virus	Abattoir worker (poultry) Agriculture (animal worker: breeder ornamental birds, poultry farmer) Veterinarian Zoo personnel	West Nile virus infection, West Nile encephalitis, West Nile fever
Yabapox virus	Veterinarian Zoo personnel	Yabapox

Allergies

Workers in the occupations described in this article are exposed to microorganisms from animals and from animal hair, body fluids and excretions that may lead to allergies. They are also exposed to dust from feed and litter that may be loaded with biological agents, and to organic dust.

According to Montano (2014), exposure of veterinarians, farmers and agricultural labourers to bioaerosols is related to hypersensitivity reactions. Farmers and workers in veterinary settings, and workers in grain threshing and sieving, flax threshing, and herb-, composting- and wood-processing settings are at an increased risk of developing chronic respiratory disorders associated with intense exposure to allergenic microorganisms (e.g. bacteria and fungi) and related pathogenic substances (Montano, 2014; Zacharisen et al., 2011). It should be noted, however, that while animals are potent causes of allergies, respiratory diseases in animal farming environments tend to be non-allergic in nature. Nevertheless, large animal farming is considered a strong risk factor for developing occupational asthma diseases, although usually not where immunoglobulin E-related responses (i.e. not through an allergenic mechanism) are concerned (May, Romberger and Poole, 2012).

Table 2 gives an overview of agents that can lead to an allergic reaction in a wider sense. In practice, and as illustrated by Table 2, it is not always easy to differentiate what exactly causes an allergic reaction, and the literature considers all allergens, irrespective of whether they originate from biological agents in the narrower sense of the term (i.e. microorganisms) or from plants, animals or insects, or even from foodstuffs. It is not always possible to differentiate a constituent of a biological agent from a chemical substance of other biological origin.

Only a few allergic agents from microorganisms, notably fungi, have been studied in practice. For example, Dutkiewicz et al. (2011), identify ß-1,3-glucanase as a general fungal allergen. However, the rubber tree also contains it (Raulf, 2016). This example illustrates the difficulties of differentiating between allergens that originate from biological agents in the narrower sense (i.e. microorganisms) and other allergens. Antigens from plant and animal origins have therefore been included under occupational allergens, as well as substances produced by microorganisms.

It is also known that fungal spores, which are particularly small, may easily penetrate the upper and lower respiratory tract (Zukiewicz-Sobczak et al., 2013). Workers' exposure to the main indoor fungi or to fungal spores increases their risk of contracting hypersensitivity pneumonitis, allergic rhinitis and allergic asthma. Allergies specific to fungal spores include some food allergies, contact allergies (skin) and allergic reactions in response to fungal infections within the organism.

Some definitions consider mites to be part of the group 'biological agents' and they are therefore included in this review too. Mites are known to induce asthma and are often impossible to avoid both at home and in occupational settings. In asthmatics, sensitisation to dust mites or cockroach antigens is seen to be as high as 61 % and 41 % respectively (Gerardi, 2010). Moreover, proteins and glycoproteins from dust mites, rodents and cockroaches are also known to induce allergenic reactions.

- **Organic dust**

Organic dust is the name given to aerosols that originate from (substances of) plants, animal feed, animals, fungi or bacteria. Different kinds of organic dust, if inhaled, may cause a variety of respiratory diseases that are known commonly as 'farmer's lung', which is recognised as an occupational disease in several EU Member States. This presents as a type of hypersensitivity pneumonitis induced by the intense or repeated inhalation of organic dusts from hay or of mould spores or any other agricultural products.

Organic dust may also contain endotoxins, large molecules found in the outer membrane of Gram-negative bacteria, released upon the destruction of the bacterial cell. Exposure to endotoxins is a risk factor for asthma. With regard to exposure to organic dust and/or endotoxins as a component of organic dust, several publications 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 and chest congestion (Basinas et al., 2013; Cambra-López et al., 2010; Diaz-Guzman, Aryal and Mannino, 2012; Duquenne, Marchand and Duchaine, 2013; Omland et al., 2014;;). In contrast, others have described a reduction in the risk of lung cancer (Lenters et al., 2010; Lundin and Checkoway, 2009) and immune-related effects (EU-OSHA, 2007) related to exposure to organic dust (endotoxins) among (livestock) farmers.

- **Allergies in agricultural workers**

Farmer's lung disease, a form of hypersensitivity pneumonitis, is probably the most common allergic complication among agricultural workers. It is caused by the inhalation of microorganisms from hay or grain stored in conditions of high humidity (Cano-Jimenez et al., 2016). Nordgren and Bailey (2016) found that dense packing of hay in warm and humid climates correlated with an increased concentration of hypersensitivity pneumonitis-causing microorganisms such as *Absidia corymbifera. O*ther common causative fungal agents, include *Eurotium amstelodami* and *Wallemia sebi* (Selman et al., 2010; Méheust et al., 2014), *Aspergillus fumigatus* and *Penicillium* (Selman et al.,2010; Cano-Jimenez et al., 2016), and *Alternaria* and *Botrytis* (Cano-Jimenez et al., 2016). Furthermore, heat and humidity have been identified as risk factors, making farmer's lung disease a more common occurrence in the south of Europe (Cano-Jimenez et al., 2016). Hypersensitivity pneumonitis has also been reported in the animal-breeding industry (in cattle, pig and poultry farmers) and in the bird-breeding industry, in relation to exposure to feed, bird serum, feather bloom and droppings (Sennekamp, 2011; Zacharisen and Fink, 2011). Pigeon breeder's disease is the avian counterpart to farmer's lung disease, caused by *Saccharopolyspora rectivirgula* (Selman et al., 2010) and exposure to bird proteins.

According to Poole (2012) there is a protective effect of growing up on the farm from the subsequent development of IgE-mediated allergic disorders. Longer exposure to occupational farming is also associated with decreased asthma risk (Wunschel and Poole, 2015). However, upper and lower respiratory adverse health effects, particularly non-IgE mediated, are common to agriculture work and represent a substantial concern for farmers, workers, and their families. Farming exposure is heterogeneous and complex and regional and international variation in farming practice should be considered.

- **Allergies in veterianarians**

Veterinarians are exposed to some of the same agents to which agricultural workers are exposed and may experience similar sensitivity reactions, including asthma and hypersensitivity pneumonitis. This includes exposure to domestic animals (cats, dogs, etc.), that is, their faeces, saliva, urine, serum, and lipocalin proteins in dander (shed fur, hair or feathers), which may induce allergic reactions in sensitised individuals. Occupational asthma and other allergic reactions are reported in agriculture (farmers), veterinary practices and laboratory work (Quirce and Bernstein, 2011; Raulf Heimsoth et al., 2011; May et al., 2012; Raulf-Heimsoth et al., 2012; Tarlo and Lemiere, 2014; Quirce et al., 2016). Asthma in veterinarians and farmers related to lipocalin proteins from horses (e.g. in dander) and cattle, respectively, is reported by Zahradnik and Raulf (2014); a prevalence of 3.6-16.5 % is indicated for horse-related allergenic effects.

- **Allergies in laboratory workers**

Laboratory workers who handle insects or laboratory animals are exposed to several allergenic agents and the potential for the immediate onset of hypersensitivity reactions from exposure to laboratory animals' urine, hair, dander and/or saliva (Corradi et al., 2013; Jones, 2015). In work that involves interaction with laboratory animals, urine holds the primary allergen (Feary et al., 2016; Raulf, 2016; Westall et al., 2014) exposure to which may result in hypersensitivity reactions that include asthma, urticaria (Tarlo and Lemiere, 2014; Zacharisen et al., 2011; Zahradnik et al., 2014; and hypersensitivity pneumonitis (Quirce et al., 2016; Sennekamp, 2011). As for other animal-related occupations, Lipocalin proteins are considered the major allergens. (Feary et al., 2016; Jones et al., 2012; Quirce and Bernstein, 2011; Raulf et al., 2016;). Rodent allergy affects between 11 % and 44 % of exposed laboratory personnel and can cause both acute and chronic symptoms, covering reactions from contact urticaria to hypersensitivity pneumonitis and asthma, and even anaphylaxis (Feary and Cullinan, 2016; Jeal and Jones, 2010; Nicholson et al., 2010; Zahradnik and Raulf, 2014).

Table 2: Overview of allergenic agents, toxins and related health effects in animal-related occupations, grouped per agent category

Biological agent	Occupation	Health effect
Animal-derived antigens ([a])		
African penguin	Animal worker	Asthma
Birds	Zoo keeper	Asthma

Biological agent	Occupation	Health effect
Bird serum, droppings, feathers (pigeon, parakeet, canary, zebra finch)	Agriculture (bird breeder) Bird dealer Veterinarian	Hypersensitivity pneumonitis
Cats	Veterinarian	Hypersensitivity pneumonitis
Chicken	Agriculture (animal worker/poultry)	Asthma
Cow bone dust	Butcher	Asthma
Deer dander	Agriculture (animal worker/farmer)	Asthma
Goat dander	Butcher, veterinarian	Asthma
Livestock animals (hair, urine, saliva, dander and other inhalable components of farm animals such as cattle, horses, pigs, sheep and goats)	Agriculture (farmer) Animal worker Veterinarian	Asthma
Mink urine	Agriculture (animal worker/farmer)	Asthma
Pig	Butcher	Asthma
Pig gut (vapour from soaking water)	Butcher (pork production)	Asthma
Poultry, turkey, wild bird, pheasant (serum, droppings, feathers)	Agriculture (animal worker/poultry)	Hypersensitivity pneumonitis
Arthropods		
Fowl mite	Agriculture (animal worker/poultry)	Asthma
Sarcoptes scabei	Animal worker (handler)	Scabies
Bacteria		
Bacteria ([b])	Agriculture (bird breeder)	Hypersensitivity pneumonitis
Mixtures		
Organic dust (endotoxin)	Agriculture (animal worker/pig farmer)	Annual lung function decline
Organic dust	Agriculture (animal worker/pigs)	Organic dust toxic syndrome, COPD

Biological agent	Occupation	Health effect
Organic dust (endotoxin, mould spores, infectious agents)	Agriculture (animal worker/poultry and pig farmer)	Respiratory disease, lower forced expiratory volume
Parasites		
Herring worm (*Anisakis simplex*)	Agriculture (animal worker/poultry farmer)	Asthma Hypersensitivity pneumonitis
Plant material		
Aromatic herbs	Butcher	Asthma
Marigold flour (*Tagetes erecta*)	Animal fodder	Asthma
Toxins/subcellular pathogens		
Aflatoxin	Agriculture (animal worker / poultry farmer)	Hepatotoxic, carcinogenic, immunosuppressive
Bacterial endotoxin	Veterinarian	([c])
Mycotoxin	Veterinarian	([c])

([a]) Allergenic biological agent.

([b]) No biological agent (exposure) was related to the corresponding health effect and occupation in one or more reviews.

([c]) No health effect was related to the corresponding biological agent (exposure) and occupation in one or more reviews.

Exposure pattern, intentional versus unintentional use and available exposure limits

Occupational exposure to biological agents can occur through the intentional use of specific microorganisms in the primary process (e.g. laboratories, biotechnological industries). It can also occur as more or less accidental or unintentional exposure that results from processes that involve many different microorganisms or working in environments in which biological agents occur naturally because the conditions are favourable for the growth of microorganisms. In general, biological agents are found in water, soil, plants and animals. Unintentional exposure is considered a serious issue in this group of occupations, as the related risk of exposure is not always obvious. Some of the health effects related to biological agents are rather unspecific, which makes it hard to estimate how frequently exposure to biological agents leads to disease. In cases of animal-related occupations, most of the exposure to biological agents is considered to be unintentional, and occurs, for instance, during contact with the animals, their body fluids and/or tissues and their faeces, but also during contact with animal feed (e.g. hay, grass, fodder beet, corn) and litter material (e.g. straw, sawdust). Depending on the composition of a specific material (e.g. availability of nutrients and water content), and its temperature and humidity (all important factors for the growth of micro-organisms), the type and quantity of micro-organisms and related biological agents, as well as the extent to which these micro-organisms survive and/or multiply, vary. The most common routes of exposure to biological agents are through inhaling airborne biological agents or by direct contact with animals or animal-related materials (mainly dermal and/or oral exposure).

Vulnerable groups

Among workers in animal-related occupations, the groups that are most vulnerable to organic dust exposure are young workers; pregnant women; people with pre-existing diseases, such as lung diseases, allergies and asthma, and diabetes (because of increased risk of infections); and people with (other) chronic diseases, as well as immunosuppressed people.

Fungal spores, for example, are especially harmful to the lungs of the immunocompromised (Zukiewicz-Sobczak et al., 2013) and may induce asthma, allergic rhinitis and hypersensitivity pneumonitis, as mentioned above.


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Moreover, on livestock farms, which are often family businesses that have a small number of people working on them and have a relatively high number of self-employed people, the situation is less easy to control than in laboratory animal facilities, as these farms are larger in scale and less advanced in terms of amenities and high levels of hygiene. Workers in a family business are therefore also considered a vulnerable group.

In addition, foreign workers employed in the animal husbandry sector often do not speak the local language well, which makes them more vulnerable, as they may have problems in understanding guidance on hygiene and other guidelines and instructions that are not provided in their native language. As in other occupations, trainees and workers in their first jobs have less practical experience and are less aware of the risks. Occupational safety and health is often not a topic of focus during the training period and therefore new workers can often lack knowledge on, for instance, the principles of hygiene. In a study evaluating work-related respiratory allergies among young workers (including laboratory animal personnel), Moscato et al. (2011) found that students starting career programmes who were exposed to allergens had a substantially higher frequency of specific sensitisation to work-related allergens, which in turn was related to atopy and bronchial hyper-responsiveness, in the first 2-3 years after exposure began. After this time, however, rates of sensitisation decreased. Furthermore, temporary or seasonal workers and undocumented workers are generally considered (more) vulnerable because they are often unaware and uninformed of the risks they are exposed to and may work under precarious conditions. Older workers are more susceptible to health problems, and, as a result of the ageing of the population, this group is increasing in size and may be increasing in these occupations too. Older workers are therefore also identified as a vulnerable group.

Emerging risks

Emerging risks, as defined by the European Risk Observatory (EU-OSHA, 2007), cover newly created or newly identified risks, increasing risks or risks that are becoming widely known or established.

An expert forecast on emerging biological risks indicated that livestock may act as a reservoir of biological agents and potentially result in global epidemics/zoonoses including diseases such as severe acute respiratory syndrome (SARS), avian influenza, Ebola and Marburg virus disease, cholera, dengue fever, measles, meningitis, yellow fever, Q-fever, legionellosis, tuberculosis, and tularaemia, all of which may be relevant to animal-related occupations (EU-OSHA, 2007).

Globalisation, different travelling and transport patterns have lead to a wider spread and higher incidence of diseases not usually seen in Europe from areas where they are endemic or within Europe (e.g. Crimean-Congo haemorrhagic fever spreading from the Balkans to Portugal and Spain), or to known diseases appearing in (workplace) settings where they have never before been observed (human dirofilariasis among veterinarians in central and eastern Europe, or sporotrichosis for example in veterinarians (caused by Sporothrix schenckii).

Furthermore, multidrug-resistant bacteria, partly due to the increased use of antibiotics in farming, are also considered an emerging risk, and potentially affect many people, including workers. As multidrug-resistant bacteria are present in both animals and humans, the increased use of antibiotics is problematic for both. The way in which animals are bred may therefore need to change to decrease the demand for antibiotics.

In addition, several countries recognise the industrialisation of livestock farming as an emerging risk, as farms increase in size (more animals, more workers) and become more efficient in production. This also increases the risk of diseases spreading more easily. A more industrialised livestock farming model may also mean that workers perform only a limited number of specialised tasks, with longer exposure times to specific risks and less variety. Depending on the type of job/task, this could lead to a longer period of (high) exposure to, for instance, organic dust. There is also concern regarding the increase in industrialised farming in other countries, which would lead to more products being imported, possibly bringing new biological agents into the country, although outsourcing certain activities could also decrease risks locally. Industrialisation may lead to additional legal obligations for employers concerning risk assessment and documentation. More attention must therefore be paid to risk assessment and how this is legally framed.

Recommended policy measures (including preventive measures) for animal-related occupations

Most of the policies identified in the expert interviews and focus groups with practitioners related to farming and the protection of agricultural workers.

OSH prevention

For farm owners and their employees, existing policies on safe work include tools for workplace risk assessment, providing information on risks in the workplace, giving recommendations to improve risk management, demonstrations of the latest protective equipment for farmers, and providing training for safety representatives. For measures such as these to succeed, personal contact, for example, a farm visit from an advisor or OSH expert, is often an important factor. It is important to consider the farmers' knowledge of work processes, to make sure that these solutions are suitable in practice. It is also important that the rules are simple and easy to understand. Financial support for farmers to implement these measures would make it easier to improve the work environment.

- **Development of a risk assessment tool**

In the focus groups with workplace practitioners, it was recommended that a risk assessment tool be developed for assessing all tasks, obtaining an overview of possible risks, and finding solutions to these risks. The blueprint for a risk inventory and evaluation (RI&E) of biological agents, as well as guidance on allergens, both developed by the Netherlands Expertise Centre for Occupational Respiratory Disorders (NECORD) (www.nkal.nl/tools.asp), are considered good examples of available tools that could be used for this purpose.

- **Exposure assessment and measurements**

In France, in companies with workers reporting health complaints, local measurements (of biological agents to identify what the workers are exposed to) are taken, and advice and assistance are given to those workers that have a health complaint and to employers to improve work processes and reduce exposure to and prevent infection from biological agents (and their constituents, often endotoxins). Research (collecting occupational hygiene samples), monitoring and performing risk assessments at farms could become easier as the sector becomes more concentrated and industrialised, meaning that agricultural businesses increase in size and decrease in number.

- **Occupational exposure limits**

Experts highlighted the need for clear maximum occupational exposure limits (OELs) for exposure to endotoxins that may put workers at considerable risk. An OEL could support the control of exposure on farms and would enable economic punishments or fines to be implemented.

However, the lack of (quantitative) data on exposure and on the associated health effects (the exposure-effect relationship) has hampered the actual derivation of OELs that are applicable in animal-related occupations. Although not specific to animal-related occupations, and not implemented as an official OEL, a health-based recommended OEL for endotoxin exposure (90 EU/m³ eight-hour time-weighted average) (DECOS/NEG, 2010) has been derived in the Netherlands and Norway. In Scandinavia, the Nordic Expert Group (NEG) has examined moulds capable of producing effects that are toxic to human health and has calculated that the level of moulds in the air at which non-sensitised workers start to experience effects is about 10^5 spores/m³ air (Eduard, 2006; Eduard, 2009). Based on the available scientific literature, the following *threshold limits or reference values* (https://oshwiki.eu/wiki/Bioaerosols_and_OSH) are available for bioaerosols in occupational environments, including in animal-related occupations:

- Total number of bacteria: ≤ 1.0×10^3-7.0×10^3 colony forming units (3) (cfu)/m³ for non-industrial workplaces and ≤ 7.5×10^2-1.0×10^7 cfu/m³ for manufacturing and industrial premises.
- Gram-negative bacteria: 1.0×10^3-2.0×10^4 cfu/m³ for manufacturing and industrial premises.
- Fungi: 1.0×10^1-1.0×10^4 cfu/m³ for non-industrial workplaces and ≤ 1.0×10^2-1.0×10^7 cfu/m³ for manufacturing and industrial premises.
- Bacterial endotoxin: 0.005-0.2 µg/m³ for productive and industrial processes.
- For pathogenic microorganisms there is no safety level; the threshold limit should be 0 cfu/m³.

- **Elimination of risks**

Advances in livestock breeding techniques as well as improvements in ergonomics and design that ensure workers' protection (including preventive measures against exposure to biological risks) should be taken into account when agricultural facilities are being designed and built. For example, ensuring good ventilation helps to reduce the risk of spreading multidrug-resistant bacteria.

Another option to consider is the automation of work processes and the separation of the worker from the areas and/or tasks that have high levels of exposure to, for instance, organic dust. One example given was that of a catch-robot used to clear sheds full of chickens.

- **Hygienic measures**

Recommendations relating to hygiene that will improve occupational safety and protection from biological agents on farms include separating living areas from occupational areas, changing clothes after work and using cleaning methods that avoid dust or aerosol formation.

The transport of animals is considered an important risk factor with regard to the spread of pathogens. Workers involved in the transport of animals and the farmers who own these animals should be made aware of the preventive measures they can take to prevent the spread of biological agents during transport, such as disinfecting the truck directly after transport.

- **Dust avoidance**

As mentioned, dust-related health problems are considered a serious problem. Measures exist to prevent the occurrence of farmer's lung and other farmers' diseases related to the growth of moulds and bacteria. These measures are especially directed towards the storage of hay and grains, and the methods of processing animal feed, litter or grains. Several examples of policies exist that provide guidance, for example, a practical booklet for pig farmers, to limit dust in pens. However, although some measures already exist for preventing organic dust exposure, there is still a great need for more measures to limit the risk of infection.

(3) Colony forming unit (cfu): a unit used to estimate the number of viable bacteria or fungal cells in a sample.

- **Personal protective equipment**

In farming, personal protective equipment (PPE) is often not worn or rejected by workers, possibly because of a lack of awareness. Another reason for the low levels of PPE use among farmers, may be the costs: they have to acquire PPE (such as respirators) themselves, which they consider to be expensive. A way to improve PPE use could include making PPE available for testing, free of charge. This has been tried with success in some countries. PPE use has also improved a little among the younger and better trained generation of farmers.

- **Training and information**

Occupational safety and health rules should apply to agriculture as they do to other industries. Farmers especially need more information on how to avoid exposure, how to reduce dust and endotoxin concentrations, and how to increase the use of PPE. An important first step would be to inform and educate farmers on regulations and rules in a clear, understandable and practical way. A second step would be to change the way that farmers work, to encourage in them an attitude of taking better care of their own health. To promote this change, practical training sessions should be considered for older generations, but training could also be provided for the new generations of farmers early on in their school curriculum, providing information on specific topics and through vocational schools. On-site training would probably be the best-fitting learning option for farmers; however, it would probably be more realistic and cost-saving to provide e-training on risk prevention.

Farmers should learn to perform a workplace risk assessment (for every work location and every work task) and to implement improvements (e.g. control of dust exposure) based on the results of the risk assessment.

Farmers should also be made more aware of the negative health effects that are linked to the way they work. For instance, the links between chronic respiratory diseases or zoonotic diseases and farm work are less obvious to farmers than the links between the work they do and serious work accidents, but these connections should also be considered in safety procedures.

Disseminating information to workers and training them are equally important, especially for foreign workers (who are a vulnerable group), as they may be unaware of the risks and may not understand occupational safety and health rules. The French ‘Certiphyto’ ([4]) scheme in agriculture has been put forward as a successful example that includes a requirement that workers achieve certification to be able to carry out certain work. A certificate as a job requirement for foreign workers would enable them to learn about how exposure can be controlled before starting work.

Avoiding the spread of antibiotic resistance

To decrease the use of antibiotics in animal farming, more detailed rules and regulations may be needed, embedded in public health or OSH legislation and as part of veterinary medicine practice. Better information, education and training could decrease the use of antibiotics. Breeders and veterinarians could cooperate on alternative strategies to the use of antibiotics. Explaining that the health-related risks linked to antibiotic use are connected to the financial risks can motivate breeders to change their behaviour and stop them from purchasing antibiotics abroad. Furthermore, awareness among the general public and consumers about how animal health and human health are connected (stressing the importance of preventing multidrug resistance, lowering the use of antibiotics, improving the understanding of zoonoses and infection by zoonotic vectors) could put pressure on farmers to change the way they breed their animals and to search for alternative methods of ensuring their animals’ welfare instead of using antibiotics.

Farmers should also be made aware that when they seek medical treatment they should inform physicians about their work with animals that entails the use of antibiotics and therefore the possible presence of multidrug-resistant bacteria. Health checks for farmers for the presence of multidrug-resistant bacteria (such as MRSA) could also be carried out, for example by occupational health services such as those established in Finland.

([4]) Website of the French Ministry of Agriculture and Food, how to get a certificate for phytopharmaceutical products (pharmaceutical agents of plant origin): http://mesdemarches.agriculture.gouv.fr/demarches/exploitation-agricole/creer-ou-ceder-une-exploitation/article/certiphyto-obtenir-le-certificat

In some countries, guidelines are available for inspectors visiting pig farms that include information on how to perform effective surveillance and ensure protection.

Occupational health services

Finland operates a unique system, the Farmers' Occupational Health Services (FOHS), which provides information, education, awareness-raising, advice and guidance on PPE, and monitoring. It also performs frequent health checks on farms, for example for farmers' lung. In addition, the FOHS can give recommendations regarding a person's ability or suitability to work given specific risks in the work environment. This is especially relevant with regard to vulnerable workers. Furthermore, regular revisions of occupational healthcare recommendations, and a blue book for occupational health inspections, are part of the service. Unfortunately, not all farms in Finland are covered by this service, but the example of the FOHS could be followed in other countries.

Conclusion

Workers in animal-related occupations are clearly at risk of infection due to unintentional exposure to bacteria, fungi, parasites, prions, organic dust (which is a mixture of (products of) biological agents), and allergenic agents, namely animal-derived antigens and toxins/pathogens. Diseases due to biological agents are widespread, which is partly as a result of the great variety in the types of exposure observed in the occupations that involve interactions with animals (e.g. abattoir workers, livestock workers and veterinarians), but also because of a lack of knowledge on prevention measures and basic hygiene rules that help to avoid exposure. Existing policy measures for animal-related occupations are directed towards the prevention of exposure to organic dust, exposure to MRSA in pig farms and farmer's lung. A number of measures have been proposed to reduce the risks in animal-related occupations including risk prevention, regulation and policy planning in occupational safety and health, monitoring and inspection, developing targeted workplace risk assessment tools, providing training and information and awareness raising. Awareness should especially be raised about the risks of exposure to biological agents in vulnerable groups such as pregnant women, young, temporary, seasonal and foreign workers, people with pre-existing diseases and immunocompromised people, as well as people working in family businesses in animal farming. Finally, preventive measures should be taken for a number of emerging risks, such as the wider geographical spread of some pathogens, risks linked to structural changes in agriculture and the spread of antibiotic resistance. Knowledge could also be improved about the causes of allergies linked to exposure to biological agents in workers in these professions, to avoid serious respiratory diseases that lead to impairment and to organise better and more targeted prevention.

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