EXPOSURE TO BIOLOGICAL AGENTS AND RELATED HEALTH PROBLEMS IN ARABLE FARMING

Health effects related to exposure to biological agents at 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 and awareness of exposure to biological agents and the related health problems, as well as the lack of a systematic approach to workplace prevention in relation to biological agents at work. In 2016, an extensive literature review was carried out on work-related diseases due to biological agents. The research confirmed that people in arable farming are at a high risk of becoming exposed to biological agents. In addition to the literature review, expert survey and collection of data on health problems and exposure from monitoring systems, information on policy measures intended to reduce the risks posed by biological agents was obtained from interviews with experts and focus group sessions with workplace practitioners. Additional information was gained during a stakeholder workshop in 2017. This article focuses on arable farming and biological agent-related health effects.

Due to their work with crops, agricultural workers (e.g. farmers, crop workers, greenhouse workers, excluding agricultural workers working with animals) are exposed to constituents of plants and parasites. The spectrum of activities and consequential exposure to a diverse range of biological agents in agricultural work results in the prevalence of various work-related diseases in these occupations. The major infection route for farmers is via inhalation of aerosols (organic dust). (EU-OSHA, 2019)

Table 1 (biological agents) and Table 2 (allergens) present a broad overview of relevant occupations and health effects. As shown, agricultural workers are exposed to a variety of types of biological agents i.e., bacteria, fungi, organic dust (which is a mixture of products of) biological agents, parasites, and viruses, and may also be exposed to endotoxins. For some biological agents, it is indicated that they can be vector[1] transmitted.

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[1] Vector: an organism that does not cause disease itself, but which 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).

Not surprisingly, a significant amount of publications describe tick-borne diseases (encephalitis, Lyme disease, Crimean-Congo haemorrhagic fever, tularaemia) as being related to arable farming (Amicizia et al., 2013; Applebaum et al., 2016; Dutkiewicz et al., 2011; Nowak-Chmura and Siuda, 2012; Rizzoli et al., 2011; Haagsma et al., 2012; Bente et al., 2013; Zukiewicz-Sobczak et al., 2013b; EU-OSHA, 2009; Canini, 2010). In 2010, in Poland, the most common occupational diseases in agriculture were reportedly (allergic) pneumoconiosis (26.9% of all diseases) and infectious and parasitic diseases (24.9%), (literature review). In this country, the incidence of occupational diseases was 418.5 per 100,000 agricultural workers and foresters. Infectious and parasitic diseases prevailed among the most commonly recognised diseases (92.4%), and Lyme disease was the most common among these (96.7%) (Zukiewicz-Sobczak et al., 2013). Relevant allergenic agents are animal-derived antigens, substances generated by arthropods and bacteria, and plant material.

As shown in Table 1, pneumoconiosis can be caused by different types of bacteria i.e. thermophilic actinomycetes, *Saccharopolyspora rectivirgula* (previously known as *Micropolyspora faeni*), and *Thermoactinomyces vulgaris, viridis and sacchari*.

Relatively few fungal infections among 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 (occasionally the beard)) are mentioned by EU-OSHA (2008) and dermatomycoses by Seyfarth & Eisner (2010). Also, mixtures of fungi (moulds) were identified as a risk (see Table 1), and may cause asthma, upper respiratory diseases, infections, coughs, headaches and flu-like symptoms, allergic diseases, and irritation of the nose, throat, eyes, and skin. Mixtures such as different fungi and endotoxins in organic dust are complex issues, because the exact cause of the disease cannot be directly related to a specific type of biological agent (EU-OSHA, 2019).

Table 1: Overview of occupations in arable farming, biological agents and related diseases.

Agent	Occupation[2]	Disease
Bacteria		
Anaplasma phagocytophilum (vector-transmitted)	Agricultural worker	Anaplasmosis
Bacillus anthracis	Agricultural worker	Anthrax
Bacillus subtilis	Crop worker	Respiratory health effects
Bacillus thuringiensis	Crop worker	Respiratory health effects
Bartonella henselae	Agricultural worker	Bartonellosis Cat scratch fever
Borrelia burgdorferi (vector-transmitted)	Crop worker	Lyme Borreliosis
Brucella spp.	Agricultural worker	Brucellosis
Campylobacter spp.	Agricultural worker	Campylobacter infection
Chlamydophila psittaci	Agricultural worker	Psittacosis

[2] The type of occupation was extracted from the publications of the literature study The occupation could either be specific (crop worker) or less specific (agricultural worker),

Agent	Occupation[2]	Disease
Coxiella burnetii (vector-transmitted)	Crop worker	Q-fever
Erysipelothrix rhusiopathiae	Agricultural worker	Erysipeloid
Escherichia coli	Agricultural worker Crop worker	
Francisella tularensis/ holartica (may be vector-transmitted)	Agricultural worker	Tularaemia
Leptospira spp. (may be vector-transmitted)	Agricultural worker, Crop worker	Leptospirosis
Methicillin resistant *Staphylococcus aureus* (MRSA)	Agricultural worker	
Mycobacterium bovis, marinum	Agricultural worker	Tuberculosis
Pasteurella multocida	Agricultural worker	
Pyrogenic germs	Agricultural worker	
Streptococcus suis	Agricultural worker	Meningitis
Saccharopolyspora	Agricultural worker	Respiratory health effects
Fungi		
Acremonium sp.	Agricultural worker	Dermatomycoses
Anthropophilic dermatophytes	Agricultural worker	Dermatomycoses (e.g. tinea pedis, athlete's foot, onychomycosis)
Basidiobulus ranarum	Agricultural worker	Dermatomycoses
Black fungi (pathogen of Chromoblastomycosis)	Agricultural worker	Dermatomycoses
Blastomyces	Agricultural worker	Blastomycosis
Cladosporium carrioni	Agricultural worker	Chromomycosis
Coccidioides	Agricultural worker	Coccidioidomycosis
Conidiobolus sp.	Agricultural worker	Dermatomycoses
Dermatophytes	Agricultural worker	Dermatomycoses
Epidermophyton	Agricultural worker	

Agent	Occupation[2]	Disease
Fonsecaea pedrosoi	Agricultural worker	Chromomycosis
Fusarium sp.	Agricultural worker	Dermatomycoses
Histoplasma capsulatum	Agricultural worker	Histoplasmosis
Indoor moulds	Agricultural worker	Asthma, upper respiratory diseases, infections, coughs, headaches and flu-like symptoms, allergic diseases, and irritation of the nose, throat, eye and skin
Lacazia loboi	Agricultural worker	Dermatomycoses
Madurella mycetomatis	Agricultural worker	Dermatomycoses
Plasmopara viticola	Agricultural worker	Asthma
Phytium insidosum	Agricultural worker	Dermatomycoses
Phialophora verrucosa	Agricultural worker	Chromomycosis
Pseudallescheria boydii	Agricultural worker	Dermatomycoses
Rhinocladiella aquaspersa	Agricultural worker	Chromomycosis
Scedosporium sp.	Agricultural worker	Dermatomycoses
Sporothrix schenckii	Agricultural worker	Sporotrichosis
Trichoderma harzianum	Crop worker	Respiratory health effects
Trichophyton	Agricultural worker	Dermatomycoses
Zoophilic dermatophytes (calves, T. verrucosum)	Agricultural worker	Dermatomycoses
Zygomycetes	Agricultural worker	Dermatomycoses
Mixtures		
Organic dust	Crop worker	Lung disease (COPD, interstitial lung disease); high fever, coughing, irritation of the respiratory system, and chest congestion (inhalation exposure)
Parasites		
Cryptosporidium spp.	Agricultural worker	Cryptosporidiosis
Dirofilaria repens	Agricultural worker	Dirofilariosis

Agent	Occupation[2]	Disease
Toxocara canis	Agricultural worker , Crop worker	
Toxoplasma gondii	Agricultural worker	Toxoplasmosis
Viruses		
Crimean Congo Haemorrhagic fever virus (vector-transmitted)	Agricultural worker	Crimean Congo haemorrhagic fever
Chikungunya virus	Agricultural worker	Chikungunya
Cowpox virus	Agricultural worker	Cowpox
Dengue virus	Agricultural worker	Dengue fever
Hanta virus	Agricultural worker	Hanta
Hendra and *Nipah* virus	Agricultural worker	Hendra and Nipah virus diseases
Hepatitis C, E virus	Agricultural worker	Hepatitis C, E
Influenza A (H7N7) (Swine and avian) influenza virus *Influenza virus*	Agricultural worker	Influenza
Louping ill virus	Agricultural worker	Influenza-like illness
Lymphocytic choriomeningitis virus (LCMV), vector-transmitted	Agricultural worker	Lymphocytic choriomeningitis
Lyssa virus	Agricultural worker	Rabies
Newcastle disease virus	Agricultural worker	Newcastle disease
Papilloma virus	Agricultural worker	Plantar, butcher warts
Parapox virus	Agricultural worker	Contagious ecthyma
Plasmodium	Agricultural worker	Malaria
Rift Valley Fever virus	Agricultural worker	Rift Valley fever
RNA virus of the genus *Flavivirus*	Agricultural worker	Yellow fever
Tickborne encephalitis virus (vector-transmitted)	Agricultural worker	Encephalitis
West Nile virus	Agricultural worker	West Nile virus infection

Table 2: Overview of occupations, allergenic agents and toxic agents and related diseases in a selection of occupations in arable farming.

Agent	Occupation	Disease
Animal-derived antigens		
Livestock animals (hair, urine, saliva, dander and other inhalable components of farm animals such as cattle, horses, pigs, sheep and goats)	Farmer	Asthma
Archaea		
Archaea in bioaerosols	Agricultural worker	Sensitisation (relevance to be determined)
Arthropods		
Two-spotted spider mite	Farmer	Asthma
House fly	Farmer	Asthma
Dust mite, citrus red mite, barn mite	Farmer	Asthma
Grain pests (*Eurygaster* and *Pyrale*)	Farmer	Asthma
Grain mite	Farmer	Asthma
Bacteria		
Bacteria	Farmer	Hypersensitivity pneumonitis
Thermophilic actinomycetes	Farmer	Asthma, hypersensitivity pneumonitis
Saccharopolyspora rectivirgula (previously known as *Micropolyspora faeni*), *Thermoactinomyces vulgaris*, *viridis* and *sacchari*	Agricultural worker	Hypersensitivity pneumonitis
Saccharopolyspora rectivirgula	Agricultural worker	Hypersensitivity pneumonitis
Plant material		
Melon, oranges	Agricultural worker	Asthma
Vetch (Vicia sativa)	Farmer	Asthma
Bell of Ireland	Grower	Asthma
Toxin / subcellular pathogen		
Endotoxin	Agriculture	COPD
Mycotoxin	Agriculture	

Allergen exposure and health effects among arable farmers

▪ Organic dust

Organic dust is a common cause of allergic respiratory diseases. For example, health statistics show that most of the occupational diseases of allergic origin reported in Polish farmers, as mentioned above, 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 (Zukiewiciz-Sobczak et al., 2013).

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

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 people exposed to grain dust (Zukiewiciz-Sobczak et al., 2013).

The main pathway leading to exposure is by inhalation of particles which reach the respiratory system. Particle deposition in lungs is closely related to their size. Many of the bioaerosol particles emitted by compost, for example, are very fine and can reach down the pulmonary alveoli. The size of spores of moulds colonizing compost (*Aspergillus*, *Penicillium*) is below 3 µm (and the one of thermophilic actinomycetes is around 1 µm (Wéry, 2014).

It is also thought that archaea may be an emerging risk as immunogenic agents in bioaerosols in agriculture and wastewater treatment plants, although the role of archaea in the aetiology of respiratory illnesses remains to be determined (Blais-Lecours et al., 2014).

Intensive breeding and technological changes in agriculture are also putting workers at risk of being exposed to organic dust.

▪ Farmer´s lung

Farmer's lung disease, a form of hypersensitivity pneumonitis, is likely the most common allergic complication in this sector. It is caused by the inhalation of microorganisms from hay or grain stored in conditions of high humidity (Cano-Jimenez et al., 2016). Symptoms of Farmer's lung are, for example, fever, rhinitis, tightness of the chest, and coughing. Nordgren & Bailey (2016) found that dense packing of hay in warm, humid climates correlated with an increased concentration of hypersensitivity pneumonitis-causing microorganisms such as *Absidia corymbifera.* Although both bacteria and fungi have been found to be causal agents of hypersensitivity pneumonitis, bacteria, particularly thermophilic actinomycetes such as *Saccharopolyspora rectivirgula* (Lecours et al., 2014; Cano-Jimenez et al., 2016), *Thermoactinomyces vulgaris*, *Thermoactinomyces viridis*, and *Thermoactinomyces sacchari* (Cano-Jimenez et al., 2016), are reported as the primary agents. Farmer's lung is becoming more common in the south of Europe (Cano-Jimenez et al., 2016). In Finland, studies have collected data on Farmer's lung since 1987 (stakeholder workshop). However, despite this large amount of information

already available, Farmer's lung is currently still a prevalent occupational disease (OD). Activities, such as cleaning storage facilities in particular, cause dust exposure, leading to Farmer's lung.

Fungal agents implicated in hypersensitivity pneumonitis in agricultural settings are primarily related to the storage conditions of raw agricultural products or animal feed (*Aspergillus* and *Penicillium*). This includes those present in hay/silage, grain, mouldy sugar cane, tobacco, mouldy grapes, mouldy onions, mouldy potatoes, peat moss, or mushrooms (Zacharisen & Fink, 2011), including Shiitake mushroom spores (Nordgren & Bailey, 2016). 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 (Méheust et al., 2014), as well as named other common causative fungal agents: notably *Eurotium amstelodami* and *Wallemia sebi* (Méheust et al., 2014; Selman et al., 2010), *Aspergillus fumigatus* and *Penicillium* (Selman et al., 2010; Cano-Jimenez et al., 2016), and *Alternaria and Botrytis (*Cano-Jimenez et al., 2016).

In addition to the evidence supporting the role of bacteria and fungi in the causation of Farmer's lung, Darby et al. (2011) indicated that the cause may be pesticide exposure rather than exposure to biological agents. Although a combined effect cannot be ruled out, this has not yet been investigated (EU-OSHA, 2019).

Lastly, working in agriculture (greenhouse workers, gardeners) is also related to occupational anaphylaxis (Moscato et al., 2014), which can result from a range of allergenic agents associated with this sector.

Exposure pattern, intentional versus unintentional use and available exposure limits

Unintentional exposures result from processes that involve many different microorganisms or environments in which biological agents occur naturally due to specific circumstances, which is also the case for arable farming environments. Agricultural workers are accidentally (unintentionally) exposed to constituents of plants and parasites. The risk of exposure is not always obvious, and the health effects may be rather unspecific – as for most occupational sectors. Therefore, it is hard to estimate how frequently exposure to biological agents leads to disease. The lack of decent (quantitative) data on exposure and the associated toxic effects (the exposure-effect relationship), hampers the actual derivation of occupational exposure limits (OELs) in practice.

Occupational exposure limits

However, the following threshold limits or reference values (OSH wiki, 'Bioaerosols and OSH[3]') are available for bioaerosols in occupational environments in the available scientific literature, including occupations in the arable farming sector:

- Total number of bacteria: ≤ $1.0x10^3$-$7.0x10^3$ colony forming units[4] (cfu) (cfu)/m^3 for non-industrial workplaces and ≤ $7.5x10^2$-$1.0x10^7$ cfu/m^3 for manufacturing and industrial premises
- Gram-negative bacteria: $1.0x10^3$-$2.0x10^4$ cfu/m^3 for manufacturing and industrial premises
- Fungi: $1.0x10^1$-$1.0x10^4$ cfu/m^3 for non-industrial workplaces and ≤ $1.0x10^2$-$1.0x10^7$ cfu/m^3 for manufacturing and industrial premises
- Bacterial endotoxin: 0.005-0.2 µg/m^3 for productive and industrial processes
- For pathogenic microorganisms there is no safety level; the threshold limit should be 0 cfu/m^3

Vulnerable groups

The identified vulnerable groups are a concern for a variety of sectors, including arable farming: trainees and workers in their first job are considered to be a vulnerable groups of workers because they have less practical experience and are less aware of the risks of biological agents pregnant women; elderly people; people with pre-existing diseases, such as lung diseases, allergies and asthma, diabetes

[3] https://oshwiki.eu/wiki/Bioaerosols_and_OSH
[4] Colony forming unit (cfu): a unit used to estimate the number of viable bacteria or fungal cells in a sample.

(because of increased risk of infections); and people with (other) chronic diseases are considered vulnerable. Furthermore, temporary workers, undocumented (illegal) workers and migrant workers are considered a relevant and (more) vulnerable in this sector because they are often unaware and uninformed of the risks they are exposed to. A vulnerable group that warrants particular attention are migrant workers, who might not be capable of reading safety instructions because of the foreign language. It is necessary that employers are aware of this fact in order to provide translations and explanations of the safety instructions and safe work practices in an accessible language.

Emerging risks

Emerging risks cover newly created or newly identified risks, increasing risks, or risks becoming widely known or established. One of the emerging issues identified in arable farming are tick-borne diseases. for-example, although recent surveys indicate that the overall prevalence of Lyme borreliosis may be stabilising, its geographical distribution is increasing, with more workers in total being exposed (EU-OSHA, 2019). In Europe, the annual number of 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 considering economics, land use and climate change predictions (Rizzoli et al., 2011). 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).

Available information on prevention/preventive measures and policy measures

In arable farming, the capacity of small and medium-sized enterprises (SMEs) to deal with risks related to exposure to biological agents is an issue. Workers are generally not aware of the risks and less easy to reach by, for example, campaigns. In addition, farmers have less (financial) means to implement control measures. It must be noted that farmers are a difficult group to reach. However, in some countries, specific programmes have been set up to raise awareness and support them in carrying out workplace risk assessment and setting prevention measures to prevent infectious diseases and allergies (from bacteria, fungi, viruses, bioaerosols, human obligate pathogens, and zoonoses).

Substances that originate from organisms such as exotoxins and allergens, and carriers of biological agents such as organic dust and bioaerosols that contribute substantially to the burden of exposure to biological agents in the work environment need to be covered by preventive measures in arable farming, where dust exposures, but also exposures linked to contact with soil may be high.

Several policy measures are known in Europe or recommended by experts. These include: 1) Advice from agricultural accident insurance institutions (incl. forestry) to promote safety technology and occupational health and safety (Germany). Providing consultancy and advice for companies, inspections of the workplace and workplace measurements and systematic evaluations of work-related disease cases, helpdesk information, a loose-leaf collection of relevant information and an instruction manual., 2) local measurements, advice and assistance in improving work processes to prevent infection in agricultural companies with ill workers (France), 3) Demonstrations of the latest

developments on protective measures incl. PPE for farmers (Denmark). The Finnish Institute of Occupational Health has also set up a job-exposure matrix for exposures to organic dust based on the workplace measurements it gathers as part of its services to enterprises.

In addition, Finland has a unique system, the Farmers' Occupational Health Services (FOHS) that provides information, education, advice, and guidance, for example in matters related to PPE, in addition to raising awareness, and monitors and performs frequent health checks at farms. Farmer's lung is also monitored and registered in the UK (reported under Ill health assessed for disablement benefit (IIDB)) and France (included in the rnv3p national database).

Conclusion

Workers in arable farming are clearly at risk of infection due to unintentional exposure to bacteria, fungi, parasites, and organic dust (which is a mixture of (products of) biological agents), parasites, toxins, viruses, and allergenic agents, namely animal-derived antigens, and substances generated by arthropods, bacteria, and plant material. The derivation of OELs would stimulate the reduction of exposure, however, to achieve this, exposure should be monitored more accurately. Moreover, workers and general practitioners need to be more aware of the link between health effects and the exposure to biological agents. Typical diseases in workers in arable farming are hypersensitivity pneumonitis, and infectious and parasitic diseases. Lyme borreliosis is an emerging risk as its geographical distribution is increasing, with more workers in total being exposed. Currently, successful policy measures exist in European countries for farmers and ill workers in agricultural companies. For example, the Farmers' Occupational Health Services in Finland provides information, education, advice and guidance and raises awareness with regard to PPE, and monitors and performs frequent health checks on farms. Furthermore, some systems monitor Farmer's lung disease in the agricultural sector such as the rnv3p in France. Such services and systems could be transferred to other European countries.

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