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Review Article

Biologically Hazardous Agents at Work and Efforts to Protect Workers' Health: A Review of Recent Reports

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ABSTRACT

Because information on biological agents in the workplace is lacking, biological hazard analyses at the workplace to securely recognize the harmful factors with biological basis are desperately needed. This review concentrates on literatures published after 2010 that attempted to detect biological hazards to humans, especially workers, and the efforts to protect them against these factors. It is important to improve the current understanding of the health hazards caused by biological factors at the workplace. In addition, this review briefly describes these factors and provides some examples of their adverse health effects. It also reviews risk assessments, protection with personal protective equipment, prevention with training of workers, regulations, as well as vaccinations.

1. Introduction

Recently, infectious diseases have been found to be most frequent among occupational diseases. Discovery of occupational infectious diseases had a lot of ripple effects in the field of occupational medicine and industrial hygiene. Occupational infections, including parasitic diseases, can limit the range of applied diagnostic and certification procedures only to diseases induced by pathogenic agents or by exposures occurring in the occupational environment [1]. In some cases, it becomes difficult or even impossible to identify the real cause of patients' complaints. Occupational biohazards are infectious agents or hazardous biological materials that exert harmful effects on workers' health, either directly thorough infection or indirectly through damage to the working environment, and it can also include medical waste or samples of a microorganism, virus, or toxin from a biological source [2].

The occupational infectious diseases are commonly found as part of a systemic infection involving the respiratory organs in immunocompromised workers. There has been a lot of discussion on biological hazards at work, their diagnosis, and treatment. Known etiological causes of the disease are increasing and include occupational factors [3]. Two main groups of biological agents are regarded as occupational biohazards: (1) allergenic and/or toxic agents forming bioaerosols, causing occupational diseases of the respiratory tract and skin, primarily in agricultural workers; and (2) agents causing zoonoses and other infectious diseases that could be spread by tick or insect vectors, through various exposure routes. Bioaerosols are biological particles of organic dust and/or droplets suspended in the air, such as viruses, bacteria, endotoxin, fungi, secondary metabolites of fungi, particles of feces, bodies of mites and insects, and feather, hair, feces, and urine of birds and mammals. They often induce disorders of the respiratory system or skin [4]. Bioaerosols are a main health problem in agriculture, medical or veterinary facilities, diagnostic laboratories, plants producing biofuel from rape blossoms, the metallurgical industry, libraries, and even art conservation [5].

This review discusses occupational exposure to biologically hazardous agents and various efforts to protect workers' health; we also provide brief commentaries on effective measures for the control and prevention of occupational infectious diseases through their systematic classifications.

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Table 1
First category of biological hazards at the workplace-contact with infected living animals

Occupations	Contact with infected living animals	Diseases
Animal breeder, animal caretaker, animal scientist, farmer and rancher, farmworker, laboratory animal worker, veterinarian	Handling of infected domestic animals (inhalation or percutaneous exposure)	Brucellosis, influenza, Hendra and Nipah virus diseases; leptospirosis; Q fever
Animal breeder, animal caretaker, animal scientist, laboratory animal worker, poultry farmer, poultry handler, veterinarian	Handling of infected chickens or birds	*Campylobacter* enteritis, influenza, Newcastle disease, psittacosis
Animal breeder, animal caretaker, animal scientist, farmer and rancher, farmworker, laboratory animal worker, veterinarian	Bite or scratch by infected dogs or cats	Brucellosis, cat scratch fever, *Capnocytophaga* infection, pasteurellosis, plague, rabies, tularemia
Farmer and rancher, farmworker, game warden, hunter and trapper, veterinarian, wildlife biologist	Bite by skunk, raccoon, bat, fox, other carnivore, or woodchuck	Rabies
Farmer and rancher, farmworker, game warden, hunter and trapper, veterinarian, wildlife biologist	Bite by rodents	Monkeypox, plague, rat bite fever
Farmer and rancher, farmworker, game warden, hunter and trapper, veterinarian, wildlife biologist	Handling of infected rodents (inhalation or percutaneous exposure)	Arenaviral infection, Hantavirus infection, Lassa fever, leptospirosis, LCM, monkeypox, Omsk hemorrhagic fever, plague
Laboratory animal worker, veterinarian	Handling of infected laboratory rats or mice	Hantavirus infection, LCM, rat bite fever
Laboratory animal worker, veterinarian	Handling of infected macaque monkeys	B-virus infection

Note. Haz-Map. Control of communicable diseases manual; "Occupational Infections" in Rom; "Occupational Infections" in LaDou. p. 280-1 [Internet]. 2012 [cited 2014 Mar 25]. Available from: http://www.haz-map.com/infect.htm.
LCM, lymphocytic choriomeningitis.

2. Materials and methods

In this review, relevant articles in the fields of biological hazards, industrial hygiene, and epidemiology were found using PubMed (http://www.ncbi.nlm.nih.gov/pubmed/), Google Scholar (http://scholar.google.com), and ScienceDirect (www.sciencedirect.com). Keywords were used to locate relevant articles, and the following is an example of a typical search: biohazard AND workplace AND worker OR environment OR occupation AND health OR industry.

These searches yielded more than 150 articles, which were further reviewed for occupational content. At the end of this selection process, 83 articles were deemed relevant to this review, and they were examined with particular emphasis on three topics: biological hazards, biological hazards associated with industries, and protection of workers against biological factors or their prevention. Prospects of industries that depend on biohazards and the significance of preventive health and safety measures in these industries have also been discussed here.

3. Results

3.1. *Basic concept of biological hazards at the workplace and their research trends in Korea*

Work-related accidents involving biological fluids in health care workers (HCWs) are among the most frequent and most serious accidents, which can lead to the development of various diseases. Occupational exposure among these workers, more specifically among nurses, can be attributed to several direct or indirect factors, such as integral and direct care to patients, administering medication and dressing wounds, cleaning and sterilization of surgical materials and diverse instruments, excessive workload [6], and inappropriate conditions for carrying out the work process.

In Korea, two main groups of biological agents are regarded as occupational hazards: allergenic and/or toxic agents forming bioaerosols, and agents causing zoonoses and other infectious diseases. Bioaerosols occurring in the agricultural work environments comprise bacteria, fungi, high-molecular-weight polymers produced by bacteria (endotoxin) or fungi (β-glucans), and low-molecular-weight secondary metabolites of fungi (mycotoxins and volatile organic compounds). It also includes various particles of plant and animal origins. All these agents can cause allergic and/or immunotoxic occupational diseases of respiratory organs (airways inflammation, rhinitis, toxic pneumonitis, hypersensitivity pneumonitis, and asthma), conjunctivitis, and dermatitis in exposed workers [7]. Very important among zoonotic agents causing occupational diseases are those causing tick-borne diseases. Recently, severe fever with thrombocytopenia syndrome (SFTS) caused by Phlebovirus (SFTS virus) and Tsutsugamushi disease caused by *Orientia tsutsugamushi* [8] have become serious social problems. Among other infectious, nonzoonotic agents, bloodborne human hepatitis and immunodeficiency viruses [human immunodeficiency virus (HIV), hepatitis B virus (HBV), and hepatitis C virus (HCV)] pose the greatest hazard to HCWs. Of interest are also bacteria causing legionellosis in people occupationally exposed to droplet aerosols, mainly from warm water [9].

Occupational infectious diseases in Korea occur mostly in people associated with industries of construction, forestry, agriculture,

Table 2
Second category of biological hazards at the workplace-contact with contaminated animal products

Occupations	Contact with contaminated animal products	Diseases
Animal Breeder, animal caretaker, animal scientist, butcher, farmer and rancher, farmworker, hunter and trapper, laboratory animal worker, meat packer, slaughterer, veterinarian	Handling of infected animal carcasses or placental tissues	Anthrax, brucellosis, Crimean Congo hemorrhagic fever, glanders, Hendra and Nipah virus infection, leptospirosis, Newcastle disease, plague, psittacosis, Q fever, Rift valley fever, *S. suis* infection, tularemia
Grader and sorter, freight handler, packer	Handling of raw goat hair, wool, or hides from endemic areas	Anthrax

Note. From the webpage of Haz-map: http://www.haz-map.com/infect.htm. Reproduced with permission.

Table 3
Third category of biological hazards at the workplace-tick, flea, or mite bite

Occupations	Tick, flea, or mite bite	Diseases
Farmer and rancher, farmworker, forester, groundskeeper, highway maintenance, hunter and trapper, landscaper, logging worker, rail track maintenance	Working in tick-infested area in North America	Babesiosis, Colorado tick fever, ehrlichiosis, Lyme disease, Powassan virus encephalitis, relapsing fever, Rocky mountain spotted fever, Southern Tick Associated Rash Illness (STARI), tick paralysis, tularemia
Building cleaning worker, pest control worker	Working in buildings infested with fleas or mites of rodents	Murine typhus, plague, rickettsialpox
Hunter and trapper, laborer	Working in mite-infested area of central, eastern, or southeast Asia	Scrub typhus

Note. From the webpage of Haz-map: http://www.haz-map.com/infect.htm. Reproduced with permission.

sanitation and similar services (i.e., hospital, healthcare services, emergency response, etc.), and food manufacturing [10]. Only a few studies have been conducted on biological factors at work. For example, a study reported regarding bacterial concentration and environmental factors in factories using water-soluble metal-working fluids [11], and another study reported about dominant microorganisms in waste-handling industries [12]. New methods are being tried to identify biological agents and analyze them, but these technologies are still in their early stages.

3.2. Classification of biological hazards at the workplace and precautions to protect workers from them

According to the website of Haz-map data [13], biological hazards can be classified into six categories: contact with infected living animals (Table 1); contact with contaminated animal products (Table 2); tick, flea, or mite bite (Table 3); contact with human or animal waste (Table 4); contact with infected patient or blood (Table 5); and raising dust containing pathogens (Table 6). This method of classifying occupational infections is commonly used because it provides a means to link diseases and occupations in the Haz-Map database. We deemed that this type of classification can explain effectively the relationship between biological hazards and occupational diseases, and is the most realistic classification to apply at the workplace.

Although described through the results of this review, the possible biological hazards associated with industries and precautions to protect workers' health are also summarized in Table 7.

Table 4
Fourth category of biological hazards at the workplace-contact with human or animal waste

Occupations	Contact with human or animal waste	Diseases
Child care worker, laboratory animal worker, veterinarian	Caring for children or primates infected with hepatitis A	Hepatitis A
Farmworker, farmer and rancher, sewer worker	Working or swimming in contaminated water (percutaneous exposure)	Leptospirosis, melioidosis, naegleriasis, schistosomiasis
Animal handler (cattle), child-care worker	Caring for children or animals infected with cryptosporidiosis	Cryptosporidiosis
Farmer and rancher, farmworker	Association with dogs in endemic areas	Echinococcosis

Note. From the webpage of Haz-map: http://www.haz-map.com/infect.htm. Reproduced with permission.

Table 5
Fifth category of biological hazards at the workplace-contact with infected patient or blood

Occupations	Contact with infected patient or blood	Diseases
Dental worker, embalmer, health care worker	Handling of contaminated needles or surgical instruments	AIDS, Crimean—Congo hemorrhagic fever, Ebola—Marburg virus infection, hepatitis B, hepatitis C, Lassa fever
Health care worker	Caring for sick patients (droplet/airborne pathogens)	Adenovirus, arenavirus infection, Crimean—Congo hemorrhagic fever, diphtheria, Ebola—Marburg virus infection, influenza, Lassa fever, measles, meningococcus, monkeypox, mumps, *Mycoplasma* infection, parvorvirus infection, pertussis, rubella, SARS, tuberculosis, Varicella
Health care worker	Caring for sick patients (bloodborne pathogens)	AIDS, arenavirus infection, Crimean—Congo hemorrhagic fever, Ebola—Marburg infection, hepatitis B, hepatitis C, Lassa fever, West Nile virus infection

Note. From the webpage of Haz-map: http://www.haz-map.com/infect.htm. Reproduced with permission.
SARS, severe acute respiratory syndrome.

Table 6
Sixth category of biological hazards at the workplace-raising of dust containing pathogens

Occupations	Raising of dust containing pathogens	Diseases
Building cleaning worker, construction worker, dockworker, farmer and rancher, farmworker, game warden, granary worker, groundskeeper, heating and air conditioning worker, hunter and trapper, pest control worker, repair worker, wildlife biologist	Raising of dust of excreta from rodents	Arenaviral infection, hantavirus infection, Lassa fever, leptospirosis, lymphocytic choriomeningitis, rat bite fever
Bridge painter, construction worker, demolition worker, farmer and rancher, farmworker, gardener, heating and air conditioning worker, roofer	Raising of dust from bird roosts, chicken coops, or bat-inhabited caves in endemic areas	Histoplasmosis
Archeologist, demolition worker, farmer and rancher, hunter and trapper, farmworker	Plowing, digging, or excavation of soil in endemic areas	Blastomycosis, coccidioidomycosis, paracoccidioidomycosis

Note. From the webpage of Haz-map: http://www.haz-map.com/infect.htm. Reproduced with permission.

Table 7
Possible biological hazards associated with occupations and precautions to protect workers' health

Occupations (industries)	Hazards and risks	Precautions
Food (cheese, yoghurt, salami) or food additive production, bakeries	Allergies caused by moulds/yeasts, bacteria, and mites; organic dusts of grain, milk powder, or flour contaminated with biological agents; toxins such as botulinustoxins or aflatoxins	Closed processes, avoiding aerosol formation, separation of contaminated work areas, appropriate hygiene measures
Health care	Several viral and bacterial infections such as HIV, hepatitis, or tuberculosis; needlestick injuries	Safe handling of infectious specimens, sharps waste, contaminated linen, and other materials; safe handling and cleaning of blood spills and other body fluids; use of adequate protective equipment, gloves, clothing, and glasses; appropriate hygienic measures
Laboratories	Infections and allergies caused by handling microorganisms and cell cultures, especially of human tissues; accidental spills and needlestick injuries	Microbiological safety cabinets, dust and aerosol-reducing measures, safe handling and transport of samples, appropriate personal protection and hygiene measures, decontamination and emergency measures for spills, restricted access, biosafety label
Agriculture, forestry, horticulture, animal food and fodder production	Bacteria, fungi, mites, and viruses transmitted from animals, parasites and ticks; respiratory problems due to microorganisms and mites in organic dusts of grain, milk powder, flour, and spices; specific allergic diseases such as farmer's lung and bird breeder's lung	Dust and aerosol-reducing measures, avoiding contacts with contaminated animals or equipment, protection against animal bites and stings, preservation of fodder, cleaning and maintenance
Metal-processing industry, wood-processing industry	Skin problems due to bacteria and bronchial asthma due to moulds/yeasts in circulating fluids used in industrial processes such as grinding, fluids used in pulp factories, and metal- and stone-cutting fluids	Local exhaust ventilation; regular maintenance, filtering, and decontamination of fluids and machinery; skin protection; 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, *Legionella*	Dust- and aerosol-reducing measures; regular maintenance of ventilation, machinery, and work areas; restricting the number of workers; maintaining high water (tap) temperatures
Archives, museums, libraries	Moulds/yeasts and bacteria causing allergies and respiratory disorders	Dust and aerosol reduction, decontamination, adequate personal protective equipment
Building and construction industry; processing of natural materials such as clay, straw, and reed; building redevelopment	Moulds and bacteria due to deterioration of building materials	Dust- and aerosol-reducing measures, appropriate personal protection and hygiene measures

Note. From the webpage of European Agency for Safety and Health at Work: https://osha.europa.eu/en. Reproduced with permission.

3.3. HCWs in hospitals, such as doctors, nurses, or emergency responders

HCWs face a wide range of occupational hazards, including needle-stick injuries, back injuries, latex allergy, and stress. In particular, occupational exposure to infectious agents, such as HIV, HBV, HCV, etc., are devastating to the victims. Infectious disease cases for which compensation is given by the Korean Workers' Compensation and Welfare Service (KCOMWEL) are increasing, and tuberculosis is the most common infectious disease for which HCWs are compensated by KCOMWEL in Korea [6]. Pulmonary diseases are well documented and diverse in many patients with HIV in clinical stages. HIV infection is usually not suspected, and HCWs may not strictly be following the safety principles that are otherwise applied when HIV infection is known or suspected, although universal precautions are routine practices. Therefore, the risk of exposure is highest and HIV transmission to HCWs is most probable [14]. Since its identification in 1985, HIV has challenged several aspects of HCWs. Because HIV is a bloodborne infectious disease, from the early days of the epidemic, concerns were raised about the risks of occupational exposures and infections among HCWs. Despite the development of a highly active antiretroviral therapy, risks of occupational infection with bloodborne pathogens remain in HCWs [15]. HIV infection poses occupational hazards to operating surgeons, especially in tropical Africa where the sero-prevalence is so high that seroconversion in medical staff contaminated with the virus is estimated to be 15 times (per annum) more than that observed in developed countries [16].

To explore the factors related to pandemic influenza A (H1N1) virus infection among HCWs, 54 HCWs working in a hospital of Beijing from 2009 to 2010 were recruited in a 1:4 matched case–control study. Factors such as influenza A (H1N1) vaccine immunization and high-protection-level masks could protect HCWs from the infection of influenza A (H1N1) [17]. An attempt had been made to reflect the state of requirements of occupational health, hygiene, and working conditions with respect to activities of the diagnostics, treatment (also surgical), and handling of such patients. Given the rapidly evolving nature of the outbreak of infection with the novel influenza A (H1N1) virus in humans, influenza vaccination is recommended as the only way to prevent the infection among HCWs [18]. The H1N1 influenza virus, which caused a global pandemic in 2009, can cause severely adverse effects to women; it also poses special medical challenges to HCWs providing obstetric care, especially during deliveries involving infected women. However, during the 2009 H1N1 influenza pandemic, the risk of nosocomial infection among obstetric care providers was not higher when respiratory infection precautions were followed [19]. HCWs pose a potential risk of transmitting communicable diseases in the hospital settings where they usually work. This review determined influenza vaccination rates among HCWs in three Middle East countries, namely, United Arab Emirates, Kuwait, and Oman, to identify the different variables associated with the noncompliance of HCWs. Influenza immunization of HCWs in these studied countries was suboptimal, which could be improved through various interventions and educational programs to increase vaccination acceptance among HCWs [20]. HCWs can be the vectors of influenza and cause influenza outbreaks. Data suggested that vaccination of nurses remains suboptimal worldwide [21].

A 40-year-old female patient presented with right-side middle ear tuberculosis. She was a nurse who had worked at the Department of Pulmonology, Clinical Hospital Rijeka in Rijeka, Croatia for 17 years. The infection was caused by *Mycobacterium tuberculosis* while she assisted in bronchoscopy. It was confirmed as an occupational disease [22].

Erysipelothrix rhusiopathiae is known as a pathogen of occupational diseases. A case of *E. rhusiopathiae* peritonitis was reported in a 50-year-old male undergoing continuous ambulatory peritoneal dialysis. *E. rhusiopathiae* was considered to be introduced through a lacerated wound on his hand when he was exposed to contaminated materials. This continuous ambulatory peritoneal dialysis peritonitis due to *E. rhusiopathiae* is the first such case reported in Asia [23].

It was reported an outbreak of pertussis with transmission between HCWs in a hospital oncology department and a patient identified as a possible source [24]. The Prosector's wart, acquired by pathologist from tuberculous cadavers has been noticeable for primary inoculation tuberculosis in HCWs with searching in Medline; however, there has been no case report of cutaneous inoculation tuberculosis in HCWs as a result of an accident during aspiration cytology [25]. A hospital surgeon, in the course of routine outpatient surgery with aspiration to collect right lumbar material in a patient with suspected tuberculosis infection, accidentally punctured the fifth finger of the left hand with the needle. This is a rare case of occupational tubercular synovitis [26]. Nosocomial transmission to the index case occurred in a hospital. After returning home, the index case became the origin of a transmission chain within the surgeons own extended family (18 further cases), from index family members to HCWs (6 cases), and from HCWs to their household contacts (1 case). Five out of six occupational cases of ebola hemorrhagic fever occurred in HCWs [27].

An immunocompetent HCW with no known history of varicella-zoster virus disease was exposed to a patient with herpes zoster and was immunized 2 days later. Twenty-seven days after receiving the varicella vaccine, while hospitalized, she developed a disseminated rash [28]. Occupationally acquired infection with methicillin-resistant *Staphylococcus aureus* (MRSA) is an issue of increasing concern. Recognized cases occurred predominantly among staff in hospitals and nursing homes. The most frequent infection sites were ears, nose, and throat, followed by skin. Only in a few cases, a genetic link between an MRSA-infected index patient and MRSA in an HCW was documented. MRSA infection was recognized as an occupational disease due to known contact with MRSA-positive patients or because workplace conditions were presumed to involve increased exposure to MRSA. As recognition of HCWs often depends on workplace characteristics the surveillance of MRSA infections in HCWs would facilitate the recognition of MRSA infections as an occupational disease [29].

Nosocomial transmission of dengue virus has been reported infrequently, and never in an Australian HCW. Clark et al described the first case of dengue virus infection occurring in a HCW in Australia following occupational exposure [30]. Although it is clear that treatment of patients with active herpes labialis lesions increases the risk of cross-infection, there are good protocols for controlling this risk. These protocols have provided practitioners with positive steps that can be taken for controlling the risk of spreading herpes infection to the dental team [31].

Extended-spectrum β-lactamases (ESBLs) in Gram-negative pathogens are increasingly prevalent in Ireland. The potential risk of occupational exposure of HCWs has not received significant attention. HCWs can be at an increased risk of acquisition of multidrug-resistant organisms such as ESBL-producing Gram-negative bacteria [32].

3.4. Personnel in laboratory

Vibrio cholerae infection is a rare but well-documented cause of laboratory-associated illness. The first case of indigenous cholera documented in Austria after more than 50 years was of a 23-year-old microbiologist who had been working with viable *V. cholerae* for 4 weeks in a practical laboratory course [33].

Brucella species is an uncommon class 3 pathogen isolated in laboratories serving nonendemic areas. Four recent cases of brucellosis were reported to be diagnosed at five different London laboratories [34]. In 2012, a positive *Brucella* culture from a harbor porpoise (*Phocoena phocoena*) was found on the coast of southern Maine, USA. An investigation was initiated regarding potential occupational exposures of staff members at the university and diagnostic laboratories who were known to have handled samples from the porpoise [35].

A needlestick injury occurred during an animal experiment in the Biosafety Level 4 Laboratory in Hamburg, Germany, in 2009. The syringe contained Zaire ebolavirus mixed with Freund's adjuvant [36]. It was the first reported case of Dengue virus infection acquired by a laboratory scientist conducting mosquito infection and transmission experiments. The exposure during laboratory-based mosquito infection and transmission experiments resulted in an acute Dengue virus infection [37]. Also, a scientist in a laboratory was accidentally infected while working with Z5463, a *Neisseria meningitidis* serogroup A strain [38].

In 2009, a local hospital reported a suspected case of fatal laboratory-acquired infection with *Yersinia pestis*, the causative agent of plague. The patient, a researcher in a university laboratory, had been working along with other members of the laboratory group with a pigmentation-negative attenuated *Y. pestis* strain (KIM D27). This report summarized the results of that investigation, which suggested that the cause of death was likely to be an unrecognized occupational exposure (route unknown) to *Y. pestis*, leading to septic shock [39]. It was the first known human case of laboratory-acquired cowpox virus infection in the United States, ensuing investigation. Handling of contaminated reagents or contact with contaminated surfaces was the likely mode of transmission [40].

3.5. Field work industries such as agriculture, fishery, and forestry

Agricultural work involves many health hazards, which can induce related health problems. However, because of low public concern and insufficient political support in the agricultural sector, agricultural health and safety are facing a serious crisis. Common work-related diseases of agricultural workers are work-related musculoskeletal diseases such as osteoarthritis of the hip and low back pain, skin diseases, pesticide poisoning, infectious and respiratory diseases, and effects of exposure to physical agents on health. For the most part, these health problems are related directly to agricultural work [41]. *Mycobacterium abscessus* infection of the hand was reported in two otherwise healthy fish handlers. *M. abscessus* can cause severe chronic tenosynovitis and should be suspected alongside the more common *Mycobacterium marinum* as a cause of nontuberculous mycobacterial hand infection due to exposure to aquatic life and fish [42].

Rhodococcus equi is a veterinary pathogen that can cause substantial morbidity in patients who are occupationally and recreationally exposed to farming, livestock, and dry soil environments. A case of occupationally acquired *R. equi* pneumonia and mediastinal lymphadenitis was reported in a study [43]. Infection with *Streptococcus suis* is common in pigs. Human infection is often related to accidental inoculation through skin injuries during occupational exposure to pigs and pork. The disease may present as meningitis, bacteremia, and less commonly as endocarditis, arthritis, or bronchopneumonia. A case of bacteremia and severe sepsis caused by *S. suis* serotype 2 was reported in a 56-year-old male with a history of prior contact with unprocessed pork. The causative agent was isolated from blood cultures and aspirated synovial fluid. This was the first report of mycotic aneurysm caused by *S. suis* in adults with a recent history of contact with pigs or unprocessed pork [44].

The serological and pathogenic properties of two *E. rhusiopathiae* isolates from human cases of infective endocarditis in Japan were characterized. One isolate was recovered from a fisherman and identified as serovar 3, which is known to be prevalent among fisherman [45]. This was the first case of hip prosthetic infection due to *Lactococcus garvieae*. A 71-year-old woman fishmonger developed hip infection 7 years after total hip arthroplasty. The infection was possibly caused by the manipulation or intake of seafood or fish contaminated with *L. garvieae* [46].

A 96-year-old Japanese man had a long working history as a breeder of fighting cocks; he developed two erythematous macules after being bitten by a cock. It was the first reported case of *Microsporum gallinae* infection in a worker in Japan [47]. A farmer was diagnosed to have pulmonary nocardiosis as an occupational disease [48]. This case was the first case of occupational pulmonary nocardiosis in Finland, where this infection is rare. Because farmers are significantly exposed to organic dusts, bacteria, and molds, it is always important to consider the possibility of an occupational disease even in the case of an acute infection [48]. Recognition of occupational etiology of borreliosis is possible only when the relationship between the infection, occupational exposure, and performed work is proved. For example, a report presented the case of a forest worker with borreliosis coexisting with tick-borne encephalitis [49].

In Mexico in 2012, outbreaks of highly pathogenic avian influenza A (H7N3) virus were reported in poultry on farms. This report described two cases of conjunctivitis without fever or respiratory symptoms caused by highly pathogenic avian influenza A (H7N3) virus infection in workers (farmers) exposed to infected poultry [50]. *M. marinum* is a photochromogenic mycobacterium that is ubiquitous in the aquatic environment. Known as "swimmer's granuloma" or "fish tank granuloma," *M. marinum* infection is an occupational hazard for aquarium cleaners and fishermen [51]. Erysipelas is an animal disease caused by Gram-positive bacterium *E. rhusiopathiae*. It is a typical animal-borne disease observed mainly in occupational groups employed in agricultural, farming (of animals and birds), fishing, and manufacturing industries [52].

Brucellosis is a systemic infectious disease, which constitutes a public health problem in Turkey. A case of brucellar (septic) monoarthritis of the knee was reported in a 74-year-old cattleman [53]. In many cases, continuous exposure to physical and chemical aggressions facilitates penetration by different fungal species, including less pathogenic species. Gardeners who are commonly exposed to soil saprophytes, have an increased risk of developing onychomycosis. Similar results have been reported previously for gardeners, farmers, forestry workers, and housewives working with soil [54]. Two cases of Sin Nombre virus infection in field workers, possibly contracted through rodent bites, were also reported [55].

3.6. Animal-care workers including veterinarians

Cryptosporidioses is a parasitic zoonotic disease caused by diverse *Cryptosporidium* species. A recently graduated student from a veterinary medical school, with a 20-week pregnancy, has been reported to be the first case demonstrating a possible cryptosporidioses transmission between humans and cats [56].

A small-animal veterinarian in Washington State, USA developed leptospirosis after an occupational exposure. Approximately 10 days prior to the onset of illness, he examined a healthy-appearing pet rat for fleas, which urinated on his ungloved hands [57]. Slaughters, tanners, stockbreeders, shepherds, butchers, veterinarians, and all those whose job requires them to work closely with animals are at a higher risk of infection and developing echinococcosis [58]. Baker–Rosenbach's erysipeloid is a skin infection caused by *E. rhusiopathiae*. It occurs essentially in humans exposed to animals colonized with this germ, such as swine. A case of chronic granulomatosis cheilitis was described in a 40-year-old farmer, which was caused by *E. rhusiopathiae*. The farmer was also a wild-boar hunter having injuries and insect bites. The diagnosis of erysipeloid was supported by epidemiological evidence (occupational exposure) [59].

A dog's groomer suffered from an abscess on the palmar side of the right hand, caused by the migration of cut dog hairs into the epidermis, which was diagnosed as an occupational interdigital sinus pilonidalis [60]. Ante- and postmortem diagnoses of rabies were established in a veterinarian who became infected during handling of herbivores with rabies [61]. Rabies is an endemic fatal zoonotic disease, commonly transmitted to humans through contact (bites and scratches) with infected animals. No history of a bite was diagnosed by physicians in Iran. The first case was a 39-year-old male veterinary technician who put his uncovered scratched hand into the mouth of a rabid bovine and became infected [62].

Orf, also known as contagious ecthyma, is a zoonotic infection caused by a dermatotropic parapoxvirus that commonly infects sheep and goats. Human infection is typically associated with occupational animal contact (animal-care workers). Orf should be included in the differential diagnosis of patients with clinically compatible skin lesions and a history of household meat processing or animal slaughter [63].

Psittacosis is a systemic zoonotic infection. The major risk factor is exposure to birds; bird owners, veterinarians, those involved with breeding and selling of birds, and commercial poultry processors are most at risk [64]. Marburg hemorrhagic fever was detected in four miners in Uganda. Infection was likely acquired through exposure to bats or bat secretions in a mine in Uganda, or through human-to-human transmission [65].

3.7. Workers in manufacturing and other industries

The presence of many workers together in semiconfined settings increases the risk of outbreaks of infectious diseases. Therefore, a single case of varicella on a cruise ship can result in a rapid spread of the disease and elevated costs for the cruise provider in terms of repatriation, ship diversion, law suits, and loss in current and potential future revenues [66].

Parapoxviruses are a genus of the double-stranded DNA family of poxviruses that infect ruminants, and zoonotic transmission to humans often results from occupational exposures. In 2009, parapoxvirus infection was diagnosed in two deer hunters in the eastern United States after the hunters had field-dressed white-tailed deer [67].

In 2006, two cases of severe pneumonia were reported in employees working at two separate mills in Finland [68]. *Legionella* serological and urinary antigen tests were used to diagnose

Legionnaires' disease in the symptomatic employees, who had worked at, or close to, waste water treatment plants. These are the first reported cases of Legionnaires' disease, associated with industrial waste water systems, in Finland [68]. *N. meningitidis* is a leading cause of bacterial meningitis and sepsis. Two cases of meningococcal disease were reported in a police officer and a respiratory therapist following occupational contact with an unconscious adult. This report describes the events of occupational transmission of *N. meningitidis* [69].

In Australia, infection with *Mycobacterium bovis* has historically been associated with employment in the livestock industry or immigration from countries in which animal disease is endemic [70].

A 37-year-old migrant worker was reported to have primary cutaneous infection due to *Cryptococcus gattii* after sustaining traumatic inoculation [71]. Livestock producers and their employees sometimes experience unintentional needlestick injury while vaccinating animals or injecting them with medications. There are only a few published reports regarding the medical complications associated with such occupational exposure [72].

Lactic acid bacteria are used in food industries as probiotic agents. Occupational exposure to inhalable dust and airborne lactic acid bacteria was measured. Based on the results, it was recommended that measures should be taken to reduce exposure to airborne lactic acid bacteria and milk powder in food industries [73].

In Japan, there had been no reports of *Mycobacterium immunogenum* isolated from metalworking fluids. The first report of isolation of the microorganism was from the sputum of a metal-grinding machine worker in Japan. The possibility of *M. immunogenum* infection in case of nontuberculosis mycobacteriosis and hypersensitivity pneumonitis in metalworkers was considered [74]. A case of an adult immunocompetent male patient working as an air-conditioning technician was reported in a study [75]. Another report described two patients with post-chikungunya rheumatism or an occupational disease [76]. In The Netherlands, a 60-year-old man presented with headache, confusion, fever, and nuchal rigidity. He worked at a meat factory. He was diagnosed to have bacterial meningitis. Particularly people who are in close contact with pigs have an increased risk of *S. suis* infection [77].

Three cases of ornithosis where that infection occurred have been reported. One was a case of a woman working in a travel agency in Cyprus and a further two cases having an occupational contact (pet shop workers) were observed to have its acute form [78].

3.8. Protection against or prevention of biological factors in workers

Protection of workers against animals, plants or several aspects of the environment with exposure to biological hazards must be used in the workplace. Measures should be taken to prevent risks of exposure to biological agents and hazards or, where this is not reasonably practicable, to reduce the risk of exposure to an acceptable level. Control measures are systems and actions used to reduce the risks of exposure to biological agents and hazards. These include engineering controls such as containment laboratories and use of microbiological safety cabinets; management controls such as safe operating procedures, training, supervision; and the use of personal protective equipment such as laboratory coats, gloves, and spectacles. The minimum and recommended control measures required for work at each containment level are specified in relevant international guidance. Biological containment laboratories, animal facilities, and plant facilities must therefore be classified into one of the three containment levels (CL 1–3). Basically, containment level 1 is for low-risk work, containment level 2 for medium-risk work, and containment level 3 for high-risk work [79].

Control measures that are used to prevent or control exposure to biological agents and hazards should be properly maintained, examined, and tested to ensure that they are working efficiently. The control measures that are subjected to detailed examination and testing include engineering controls; local exhaust ventilation, which includes microbiological safety cabinets and extract ventilation for equipment; and respiratory protective equipment. Proper storage, transport, and destruction or inactivation of biological hazards; disinfection; autoclaving; waste management and disposal; health surveillance; monitoring exposure and immunization; emergency procedures including emergency contacts; information; as well as instruction, training, and supervision are also required.

3.9. Personal Protective Equipment (PPE)

It was suggested that gardeners are also at a risk of onychomycosis. Therefore, to avoid onychomycosis, they need to wear shoes, keep their feet cool and dry, keep their wounds covered, wash their hands and feet properly after work, and wear gloves during work [54]. This illness in a veterinarian (outlined above) might have been prevented, if the veterinarian had been wearing gloves during examination, as recommended by the National Institutes for Zoonotic Disease Prevention in Veterinary Personnel [57]. Workers and employers with these exposure risks should also undergo counseling regarding the use of nonpermeable gloves and hand hygiene to prevent infection [63].

3.10. Risk assessment

A significant association between occupational exposure to swine and human required for infection in primates, cohort, and case–control studies in humans, and formal risk assessment are recommended before specific public-health policy actions are taken [80]. *S. suis* infection in humans mainly occurs among risk groups that have frequent exposure to pigs or raw pork. Prevention through public health surveillance is recommended, especially for individuals with occupational exposures to swine and raw pork [81]. Although medical complications from farm-related needlestick injuries do not appear to be common, producers and employees who inject livestock need to be aware of the related risks and take measures to decrease unintentional needlestick injury [72].

3.11. Training of workers

In laboratory personnel, training is a very important aspect of staff protection. Employers should provide adequate infection-control training to possibly exposed workers and report notifiable diseases promptly [69]. The most important methods for the prevention of infectious diseases among laboratory workers are to protect them against direct contact with biological material, apply vaccinations, and implement proper postexposure procedures. Appropriate habits of workers are relevant to the prevention of infections in workplaces. It is necessary to develop practical instructions aimed at improving occupational safety to protect this occupational group against harmful effects of biological agents [82]. A relationship between knowledge, risk perception, and vaccination behaviors among nurses was confirmed. The identified sentinel items of knowledge and risk perception can be useful for future vaccination campaigns [21]. A large number of patients with occupational ebola hemorrhagic fever even after the implementation of barrier nursing pointed at the need to strengthen training and supervision of local HCWs [27]. It should be acknowledged that medical diagnostic laboratories pose significantly increased risks to the health of laboratory workers. Therefore, properly worked out and obeyed procedures ensuring safety in work with biological material and microbes, and properly trained laboratory staff play essential roles in reducing the risk. Appropriate qualifications and habits of workers developed through training are of relevance to the prevention of infections in laboratories [82]. A more comprehensive study is required to assess accurately the level of occupational risk to HCWs in the acquisition of ESBL-producing organisms and their onward transmission to household contacts [32]. It also highlights the importance of appropriate laboratory practices for containing infected mosquitoes and preventing contact with potentially infectious material, including the generation of potentially infectious aerosols [37]. Researchers should adhere to recommended biosafety practices when handling any live bacterial cultures, even attenuated strains, and public institutions should implement and maintain effective surveillance systems to detect and monitor unexpected acute illness in laboratory workers [39]. In addition, biowaste management should be supported through appropriate education, training, and commitment of health care staff, management, and health care managers within an effective policy and legislative framework.

3.12. Regulations

To achieve the target of a clean environment and save valuable life, all should know and understand the value and strategy of management of biohazards. An attempt was made to provide an overview of the literature on the transmission of HBV from HCWs to patients and the current recommendations that vary from province to province. Establishment of national guidelines to standardize monitoring of occupational infection among HCWs would improve health care workplace safety and patient care [83]. To our knowledge, only a few, if any, public agencies provide specific guidelines pertaining to empirical treatment of severe infections for their local HCWs in the event of hospitalization. Local resistance patterns of pathogens in each hospital may assert the necessity of such a guideline [32]. The potential of *Brucella* for human infection and illness, as well as the intensity, duration, and expense of the follow-up recommended for *Brucella* exposure, highlights the need for developing standard protocols by facilities to prevent exposures during the handling of marine mammals, particularly during aerosol-generating procedures [35]. It is also important for small-animal veterinarians to minimize their infection risk by practicing recommended infection control procedures. Veterinarians should establish and follow a written infection control plan based on the standardized infection control approach, to minimize their risk of occupational zoonotic infections [57].

3.13. Vaccination

Given the rapidly evolving nature of the outbreak of novel influenza A (H1N1) virus infection in humans, influenza vaccination is recommended as the only way to prevent infection of HCWs and patients with underlying medical conditions [18]. Although testing for varicella immunoglobulin (Ig)G and IgM antibodies, followed by vaccination when necessary, was a cost-effective method to prevent an expensive outbreak in the semiconfined setting of a cruise ship, it was recommended as a mandatory part of the pre-employment medical examination for Indian seafarers [66]. Based on a risk–benefit assessment, it was recommended that the exposed person take an experimental vaccine that had shown postexposure prophylaxis efficacy in Zaire ebolavirus-infected nonhuman primates [36].

4. Discussion

Two main groups of biological agents are regarded as occupational hazards: allergenic and/or toxic agents forming bioaerosols, and agents causing zoonoses and other infectious diseases. All these agents can be a cause of allergic and/or immunotoxic occupational diseases of respiratory organ (airways inflammation, rhinitis, toxic pneumonitis, hypersensitivity pneumonitis, and asthma), conjunctivitis, and dermatitis in exposed workers. Among other infectious, nonzoonotic agents, bloodborne human hepatitis and immunodeficiency viruses pose the greatest hazards to HCWs. Of interest are also bacteria causing legionellosis in people occupationally exposed to droplet aerosols, mainly from warm water. Sources of biological hazards include bacteria, viruses, insects, plants, birds, animals, and humans. These hazards can cause a variety of health problems, ranging from skin irritation and allergies to infections (tuberculosis and AIDS), cancer (liver cancer, and HBV or HCV infection), and so on. Several classes of pathogens, including bacteria, viruses, fungi, parasites, and prions, can cause infection. Modes of transmission vary depending on the type of organism; some infectious agents may be transmitted by more than one route: some are transmitted primarily by direct or indirect contact, and others by droplet or airborne routes. Other infectious agents, such as bloodborne viruses (HBV, HCV, and HIV), are transmitted via percutaneous or mucous membrane exposure. Importantly, not all infectious agents are transmitted from person to person. Infection is the result of a complex interrelationship between a potential host and an infectious agent. Most of the factors that influence infection and the occurrence and severity of disease are related to the host. However, characteristics of the host–agent interaction, as it relates to pathogenicity, virulence, and antigenicity, are also important, as are the infectious dose, mechanisms of disease production, and route of exposure.

In this review, we focused on some specific occupations such as those of HCWs, laboratory workers, field workers, animal-care workers, and workers in manufacturing industries. Many occupations may expose the workers to biological agents. You can find a complete picture on the website of Haz-map: http://www.haz-map.com/infect.htm (Tables 1–6) [13].

Biological risks at the workplace can be prevented by maintaining good hygiene and sanitation. For this reason, most countries have developed a uniform approach called "standard precautions." Originally developed for hospitals, standard precautions have been adopted at a wide range of workplaces. They apply to all situations where workers have risk of exposure to blood or certain body fluids, and aim at preventing exposure to bloodborne diseases transmitted through needlestick accidents or by fluid contact with an open wound, nonintact skin, or mucous membranes. Education programs for workers about personal hygiene practices should emphasize that careful hand washing is extremely important in the prevention of diseases. Workers should be informed about using appropriate protective clothing and removing it at the end of the shift. They should also be informed about the necessity of washing hands frequently, and prior to eating, drinking, or smoking; they should also avoid nail biting. Many vaccines are available. Some of them are mandatory for specific occupational groups (HBV vaccine for HCWs) in many countries, some are occasionally mandatory (BCG for HCWs), and some are just recommended (tetanus for construction workers). Training in laboratory practice is a very important aspect of staff protection. Guidelines published by Centers for Disease Control and Prevention (Atlanta, USA) in preventing the transmission of tuberculous infection in health care settings must be adhered to [19]. In addition, a brief commentary is offered on effective measures for the control and prevention of occupational infectious diseases and their transmission among workers [6].

Recently, as a fundamental measure to systematically prevent occupational infectious diseases, our Occupational Safety and Health Research Institute in Korea Occupational Safety and Health Agency (OSHRI, KOSHA) tried to develop an at-a-glance handbook about these biological factors. This handbook provides precise information on biological hazardous agents encountered at the workplace, to protect workers. More effective classification system of occupational infectious diseases was presented, thereby distinguishing biologically hazardous agents, the occupations, industries, and infectious diseases, and connecting them to the related workers. Many industries in Korea, which are expected to generate major infectious occupational-related biological factors, focus on this handbook that contains information on a total of 60 species and use it with convenience for practical utility. In conclusion, because information on biological agents in the workplace is lacking, biological hazard analyses at the workplace to securely recognize the harmful factors with biological basis are desperately needed. Modes of transmission vary depending on the type of organism; some infectious agents may be transmitted by more than one route: some are transmitted primarily by direct or indirect contact, while others are transmitted by droplet, or airborne routes.

In this review, we focused on some specific occupations such as those of HCWs, laboratory workers, field workers, animal-care workers, and workers in manufacturing industries. We concentrated on literatures published after 2010 that attempted to detect biological hazards to humans, especially workers, and the efforts to protect them against these factors. In addition, this review briefly describes these factors, providing examples of their adverse health effects, risk assessments, protection with personal protective equipment, prevention with training of workers, regulations, as well as vaccinations.

Biological risks at the workplace can be prevented by maintaining good hygiene and sanitation. Education programs for workers about personal hygiene practices should emphasize that careful hand washing is extremely important in the prevention of diseases. Workers should be informed about using appropriate protective clothing and removing it at the end of the shift. Many vaccines are available. Some of them are mandatory in many countries, for specific occupational groups. Training in laboratory practice is a very important aspect of staff protection. Guidelines and even a few brief commentaries are offered on effective measures for the control and prevention of occupational infectious diseases and their transmission among workers.

Recently, as a fundamental measure to systematically prevent occupational infectious diseases, OSHRI, KOSHA, tried to develop an at-a-glance handbook about these biological factors. This handbook provides precise information on biological hazardous agents at the workplace, to protect workers. More effective classification systems of occupational infectious diseases was presented, thereby distinguishing biologically hazardous agents, the occupations, industries, infectious diseases, and connecting them to the related workers. It is expected to generate the major infectious occupational-related biological factors, focusing on this handbook with a total of 60 species, and used with convenience for practical utility.

Conflicts of interest

No potential conflicts of interest relevant to this article were reported.

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References

[1] Lipiniska-Ojrzanowska A, Wittczak T, Krzyczmanik D, Palczynski C, Walusiak-Skorupa J. Invasion by trichinae in the patient hospitalized with suspicion of occupational borreliosis: a case report. Med Pr 2011;62:73–6.

[2] Wikipedia. Biological hazard [Internet]. San Francisco (CA); 2010 [cited 2014 Mar 10]. Available from: http://en.wikipedia.org/wiki/Biological_hazard.

[3] Liu YC, Zhou SH, Ling L. Aetiological factors contributing to the development of primary laryngeal aspergillosis in immunocompetent patients. J Med Microbiol 2010;59:1250–3.

[4] Ławniczek-Wałczyk A, Gorny RL. Endotoxins and β-glucans as markers of microbiological contamination – characteristics, detection, and environmental exposure. Ann Agric Environ Med 2010;17:193–208.

[5] Jacobsen G, Schaumburg I, Sigsgaard T, Schlunssen V. Non-malignant respiratory diseases and occupational exposure to wood dust. Part I. Fresh wood and mixed wood industry. Ann Agric Environ Med 2010;17:15–28.

[6] Kang JO. Occupational infections of health care personnel in Korea. Hanyang Med Rev 2011;31:200–10.

[7] Yeo HG, Kim JH. SPM and fungal spores in the ambient air of west Korea during the Asian dust (Yellow sand) period. Atmos Environ 2002;36:5437–42.

[8] Kim KH, Yi J, Kim G, Choi SJ, Kang IJ, Kim NH, Choe PG, Kim NJ, Lee JK, Oh M. Severe fever with thrombocytopenia syndrome, South Korea, 2012. Emerg Infect Dis 2013;19:1892–4.

[9] Dutkiewicz J, Cisak E, Sroka J, Wójcik-Fatla A, Zając V. Biological agents as occupational hazards—selected issues. Ann Agric Environ Med 2011;18:286–93.

[10] Korea Occupational Safety and Health Agency (KOSHA). Statistics on occupational accidents, from 2002 to 2011 [Internet]. Ulsan (Korea): KOSHANET; 2013 [cited 2014 Mar 25]. Available from: http://www.kosha.or.kr/board.do?menuId=554.

[11] Park HD, Park H, Kim JH, Jang JK. A study of the relations between the bacterial concentration and the environmental factors in the factories using water soluble metal working fluids. J Korean Soc Occup Environ Hyg 2012;22:284–92 [in Korean].

[12] Park HD, Park H. A study of dominant microorganisms in waste handling industries. J Korean Soc Occup Environ Hyg 2013;23:84–94 [in Korean].

[13] Haz-Map. Control of communicable diseases manual; "Occupational Infections" in Rom; "Occupational Infections" in LaDou. p. 280–1 [Internet]. Bethesda (MD): U.S. National Library of Medicine; 2012 [cited 2014 Mar 25]. Available from: http://www.haz-map.com/infect.htm.

[14] Miše K, Vuckovic M, Jurcev-Savicevic A, Gudelj I, Peric I, Miše J. Undiagnosed AIDS in patients with progressive dyspnoea: an occupational risk for healthcare workers in Croatia. Arh Hig Rada Toksikol 2011;62:57–64.

[15] Henderson DK. Management of needlestick injuries: a house officer who has a needlestick. JAMA 2012;307:75–84.

[16] Alhassan SU, Aji SA. Transurethral prostatectomy in human immunodeficiency virus-infected patients, morbidity and surgical risks in a developing economy. Ann Afr Med 2012;11:48–50.

[17] Deng Y, Zhang Y, Wang XL, Liu WT, Duan W, Yang P, Pang XH, Wang QY. Pandemic influenza A (H1N1) virus infection factors among healthcare workers—a case–control study. Zhonghua Yu Fang Yi Xue Za Zhi 2010;44:1075–8 [in Chinese].

[18] Vernadakis S, Adamzik M, Heuer M, Antoch G, Baba H, Fiedler M, Buer J, Paul A, Kaiser GM. Hemicolectomy for ischemic colitis: a case report of a (H1N1) virus-associated death. Chirurg 2010;81:841–5 [in German].

[19] Liu YX, Jia N, Suo JJ, Du MM, Gao ZY, Yi JM, Xing YB, Liu G, Zhang SB, Liu L, Yao W, He T, Xiao HJ, Jia N, Gao Y. Assessment of the risk of nosocomial 2009 H1N1 influenza infection among obstetric care workers. Int J Gynaecol Obstet 2011;112:140–8.

[20] Abu-Gharbieh E, Fahmy S, Rasool BA, Khan S. Influenza vaccination: healthcare workers attitude in three Middle East countries. Int J Med Sci 2010;7:319–25.

[21] Zhang J, While AE, Norman IJ. Nurses' knowledge and risk perception towards seasonal influenza and vaccination and their vaccination behaviours: a cross-sectional survey. Int J Nurs Stud 2011;48:1281–9.

[22] Lalic H, Kukuljan M, Pavicic MD. A case report of occupational middle ear tuberculosis in a nurse. Arh Hig Rada Toksikol 2010;61:333–7.

[23] Shin SJ, Gwak WG. *Erysipelothrix rhusiopathiae* peritonitis in a patient undergoing continuous ambulatory peritoneal dialysis. J Korean Med Sci 2010;25:1234–6.

[24] Baugh V, McCarthy N. Outbreak of *Bordetella pertussis* among oncology nurse specialists. Occup Med (Lond) 2010;60:401–5.

[25] Harris SH, Khan R, Verma AK, Ahmad S. Finger ulceration in a healthcare professional. Ann Afr Med 2010;9:45–7.

[26] Delli Carri R, Piscozzi P, Massimelli M, Falcetta R. A rare case of tubercular tenosynovitis in hospital surgeon as a result of an occupational accident caused by puncture with an infected needle. Prevention aspects and legal–medical evaluation. Med Lav 2010;101:26–9.

[27] Borchert M, Mutyaba I, Van Kerkhove MD, Lutwama J, Luwaga H, Bisoborwa G, Turyagaruka J, Pirard P, Ndayimirije N, Roddy P, Van Der Stuyft P. Ebola haemorrhagic fever outbreak in Masindi District, Uganda: outbreak description and lessons learned. BMC Infect Dis 2011;11:357.

[28] Bernstein P, Furuya Y, Steinberg S, Scully B, Larussa P, Gershon AA. Vaccine-related varicella-zoster rash in a hospitalized immunocompetent patient. Am J Infect Control 2011;39:247–9.

[29] Haamann F, Dulon M, Nienhaus A. MRSA as an occupational disease: a case series. Int Arch Occup Environ Health 2011;84:259–66.

[30] Clark BM, Molton JS, Habib T, Williams DT, Weston EL, Smith DW. Dengue virus infection in Australia following occupational exposure: a reflection of increasing numbers of imported cases. J Clin Virol 2012;54:376–7.

[31] Browning WD, McCarthy JP. A case series: herpes simplex virus as an occupational hazard. J Esthet Restor Dent 2012;24:61–6.

[32] Cotter M, Boyle F, Khan A, Boo TW, O'Connell B. Dissemination of extended-spectrum ß-lactamase-producing *Escherichia coli* at home: a potential occupational hazard for healthcare workers? J Hosp Infect 2012;80:100–1.
[33] Huhulescu S, Leitner E, Feierl G, Allerberger F. Laboratory-acquired *Vibrio cholerae* O1 infection in Austria, 2008. Clin Microbiol Infect 2010;16:1303–4.
[34] Reddy S, Manuel R, Sheridan E, Sadler G, Patel S, Riley P. Brucellosis in the UK: a risk to laboratory workers? Recommendations for prevention and management of laboratory exposure. J Clin Pathol 2010;63:90–2.
[35] Centers for Disease Control and Prevention. Human exposures to marine *Brucella* isolated from a harbor porpoise—Maine, 2012. MMWR Morb Mortal Wkly Rep 2012;61:461–3.
[36] Günther S, Feldmann H, Geisbert TW, Hensley LE, Rollin PE, Nichol ST, Ströher U, Artsob H, Peters CJ, Ksiazek TG, Becker S, ter Meulen J, Olschläger S, Schmidt-Chanasit J, Sudeck H, Burchard GD, Schmiedel S. Management of accidental exposure to Ebola virus in the biosafety level 4 laboratory, Hamburg, Germany. J Infect Dis 2011;204:S785–90.
[37] Britton S, van den Hurk AF, Simmons RJ, Pyke AT, Northill JA, McCarthy J, McCormack J. Laboratory-acquired dengue virus infection—a case report. PLoS Negl Trop Dis 2011;5:e1324.
[38] Omer H, Rose G, Jolley KA, Frapy E, Zahar JR, Maiden MC, Bentley SD, Tinsley CR, Nassif X, Bille E. Genotypic and phenotypic modifications of *Neisseria meningitidis* after an accidental human passage. PLoS One 2011;6:e17145.
[39] Centers for Disease Control and Prevention. Fatal laboratory-acquired infection with an attenuated *Yersinia pestis* strain—Chicago, Illinois, 2009. MMWR Morb Mortal Wkly Rep 2011;60:201–5.
[40] McCollum AM, Austin C, Nawrocki J, Howland J, Pryde J, Vaid A, Holmes D, Weil MR, Li Y, Wilkins K, Zhao H, Smith SK, Karem K, Reynolds MG, Damon IK. Investigation of the first laboratory-acquired human cowpox virus infection in the United States. J Infect Dis 2012;206:63–8.
[41] Roh S. Work-related diseases of agricultural workers in South Korea. J Korean Med Assoc 2012;55:1063–9.
[42] Kang GC, Gan AW, Yam A, Tan AB, Tay SC. *Mycobacterium abscessus* hand infections in immunocompetent fish handlers: case report. J Hand Surg Am 2010;35:1142–5.
[43] Yamshchikov AV, Schuetz A, Lyon GM. *Rhodococcus equi* infection. Lancet Infect Dis 2010;10:350–9.
[44] Laohapensang K, Rutherford RB, Arworn S. Mycotic abdominal aortic aneurysm due to *Streptococcus suis*: a case report. Surg Infect (Larchmt) 2010;11:179–81.
[45] Harada K, Amano K, Akimoto S, Yamamoto K, Yamamoto Y, Yanagihara K, Kohno S, Kishida N, Takahashi T. Serological and pathogenic characterization of *Erysipelothrix rhusiopathiae* isolates from two human cases of endocarditis in Japan. New Microbiol 2011;34:409–12.
[46] Aubin GG, Bémer P, Guillouzouic A, Crémet L, Touchais S, Fraquet N, Boutoille D, Reynaud A, Lepelletier D, Corvec S. First report of a hip prosthetic and joint infection caused by *Lactococcus garvieae* in a woman fishmonger. J Clin Microbiol 2011;49:2074–6.
[47] Miyasato H, Yamaguchi S, Taira K, Hosokawa A, Kayo S, Sano A, Uezato H, Takahashi K. Tinea corporis caused by *Microsporum gallinae*: first clinical case in Japan. J Dermatol 2011;38:473–8.
[48] Kupila N, Kankaanranta H, Sauni R. Pulmonary nocardiosis in a farmer. Duodecim 2011;127:2315–9.
[49] Krzyczmanik D, Rybacki M, Wittczak T, Dudek W, Swierczynska-Machura D, Palczynski C, Walusiak-Skorupa J. Coexistence of two occupational infectious diseases in one patient—borreliosis and tick-borne encephalitis—a case report. Med Pr 2011;62:339–44.
[50] Centers for Disease Control and Prevention. Notes from the field: highly pathogenic avian influenza A (H7N3) virus infection in two poultry workers—Jalisco, Mexico, July 2012. MMWR Morb Mortal Wkly Rep 2012;61:726–7.
[51] Jacobs S, George A, Papanicolaou GA, Lacouture ME, Tan BH, Jakubowski AA, Kaltsas A. Disseminated *Mycobacterium marinum* infection in a hematopoietic stem cell transplant recipient. Transpl Infect Dis 2012;14:410–4.
[52] Andrychowski J, Jasielski P, Netczuk T, Czernicki Z. Empyema in spinal canal in thoracic region, abscesses in paravertebral space, spondylitis: in clinical course of zoonosis *Erysipelothrix rhusiopathiae*. Eur Spine J 2012;21:S557–63.
[53] Cerit ET, Aydin M, Azap A. A case of brucellar monoarthritis and review of the literature. Rheumatol Int 2012;32:1465–8.
[54] Jandial S, Sumbali G. Fusarial onychomycosis among gardeners: a report of two cases. Indian J Dermatol Venereol Leprol 2012;78:229 [letter].
[55] Torres-Perez F, Wilson L, Collinge SK, Harmon H, Ray C, Medina RA, Hjelle B. Sin Nombre virus infection in field workers, Colorado, USA. Emerg Infect Dis 2010;16:308–10.
[56] Neira P, Muñoz N, Rosales J. *Cryptosporidium parvum* infection in a pregnant immunocompetent woman with occupational risk. Rev Chilena Infectol 2010;27:345–9.
[57] Baer R, Turnberg W, Yu D, Wohrle R. Leptospirosis in a small animal veterinarian: reminder to follow standardized infection control procedures. Zoonoses Public Health 2010;57:281–4.
[58] Farahmand M, Yadollahi M. Echinococcosis: an occupational disease. Int J Occup Environ Med 2010;1:88–91.
[59] Koufane J, Afifi Y, Khoudri I, Rmili M, Senouci K, Kettani F, Benouda A, Hassam B, Ismaili N. Baker Rosenbach erysipeloid appearing as a granulomatous cheilitis. Ann Dermatol Venereol 2010;137:124–7.
[60] Fransen SA, Hanneman P. A dog's groomer with a painful hand. Ned Tijdschr Geneeskd 2011;155:A1718 [abstract].
[61] Brito MG, Chamone TL, da Silva FJ, Wada MY, Miranda AB, Castilho JG, Carrieri ML, Kotait I, Lemos FL. Antemortem diagnosis of human rabies in a veterinarian infected when handling a herbivore in Minas Gerais, Brazil. Rev Inst Med Trop Sao Paulo 2011;53:39–44.
[62] Simani S, Fayaz A, Rahimi P, Eslami N, Howeizi N, Biglari P. Six fatal cases of classical rabies virus without biting incidents, Iran 1990–2010. J Clin Virol 2012;54:251–4.
[63] Centers for Disease Control and Prevention. Human Orf virus infection from household exposures—United States, 2009-2011. MMWR Morb Mortal Wkly Rep 2012;61:245–8.
[64] Stewardson AJ, Grayson ML. Psittacosis. Infect Dis Clin North Am 2010;24:7–25.
[65] Adjemian J, Farnon EC, Tschioko F, Wamala JF, Byaruhanga E, Bwire GS, Kansiime E, Kagirita A, Ahimbisibwe S, Katunguka F, Jeffs B, Lutwama JJ, Downing R, Tappero JW, Formenty P, Amman B, Manning C, Towner J, Nichol ST, Rollin PE. Outbreak of Marburg hemorrhagic fever among miners in Kamwenge and Ibanda districts, Uganda, 2007. J Infect Dis 2011;204:S796–9.
[66] Idnani N. Varicella among seafarers: a case study on testing and vaccination as a cost-effective method of prevention. Int Marit Health 2010;61:32–5.
[67] Roess AA, Galan A, Kitces E, Li Y, Zhao H, Paddock CD, Adem P, Goldsmith CS, Miller D, Reynolds MG, Zaki SR, Damon IK. Novel deer-associated parapoxvirus infection in deer hunters. N Engl J Med 2010;363:2621–7.
[68] Kusnetsov J, Neuvonen LK, Korpio T, Uldum SA, Mentula S, Putus T, Tran Minh NN, Martimo KP. Two Legionnaires' disease cases associated with industrial waste water treatment plants: a case report. BMC Infect Dis 2010;10:343.
[69] Centers for Disease Control and Prevention. Occupational transmission of *Neisseria meningitidis*—California, 2009. MMWR Morb Mortal Wkly Rep 2010;59:1480–3.
[70] Ingram PR, Bremner P, Inglis TJ, Murray RJ, Cousins DV. Zoonotic tuberculosis: on the decline. Commun Dis Intell Q Rep 2010;34:339–41.
[71] Lingegowda BP, Koh TH, Ong HS, Tan TT. Primary cutaneous cryptococcosis due to *Cryptococcus gattii* in Singapore. Singapore Med J 2011;52:e160–2.
[72] Jennissen C, Wallace J, Donham K, Rendell D, Brumby S. Unintentional needlestick injuries in livestock production: a case series and review. J Agromedicine 2011;16:58–71.
[73] Zeilfelder B, Chouanière D, Reboux G, Vacheyrou M, Milon A, Wild P, Oppliger A. Health effects of occupational exposure in a dairy food industry, with a specific assessment of exposure to airborne lactic acid bacteria. J Occup Environ Med 2012;54:969–73.
[74] Omura H, Kajiki A, Ikegame S, Aono A, Mitarai S, Kitahara Y. *Mycobacterium immunogenum* isolated from a metal worker in Japan. Kekkaku 2012;87:341–4 [in Japanese].
[75] Rabie NB, Althaqafi AO. *Rhizopus*-associated soft tissue infection in an immunocompetent air-conditioning technician after a road traffic accident: a case report and review of the literature. J Infect Public Health 2012;5:109–11.
[76] Simon F, Javelle E. Administrative issues linked to health insurance coverage of chronic post-chikungunya rheumatism. Med Trop (Mars) 2012;72:99–102.
[77] de Ceuster LM, van Dillen JJ, Wever PC, Rozemeijer W, Louwerse ES. *Streptococcus suis* meningitis in a meat factory employee. Ned Tijdschr Geneeskd 2012;156:A5080 [in Dutch] [abstract].
[78] Nafeyev AA, Savinova GA, Rechnik VN, Voloshina OA, Vinogradova IB. Problems in the diagnosis of ornithosis. Ter Arkh 2012;84:64–5 [In Russian].
[79] University of Glasgow. Safety and Environmental Protection Services. Controlling risks of work with biological agents and hazards [Internet]. Glasgow (UK): University of Glasgow, Pearce Lodge; 2014 [cited 2014 Mar 25]. Available from: http://www.gla.ac.uk/services/seps/a-z%20index/biological%20safety/biologicalcoshhriskassessment/controlling%20risks%20of%20work%20with%20biological%20agents%20a.
[80] Wilhelm BJ, Rajic A, Greig J, Waddell L, Trottier G, Houde A, Harris J, Borden LN, Price C. A systematic review/meta-analysis of primary research investigating swine, pork or pork products as a source of zoonotic hepatitis E virus. Epidemiol Infect 2011;139:1127–44.
[81] Huh HJ, Park KJ, Jang JH, Lee M, Lee JH, Ahn YH, Kang CI, Ki CS, Lee NY. *Streptococcus suis* meningitis with bilateral sensorineural hearing loss. Korean J Lab Med 2011;31:205–11.
[82] Kozajda A, Szadkowska-Stanczyk I. Protection of medical diagnostic laboratory workers against biohazards. Med Pr 2011;62:291–5 [In Polish].
[83] Bhat M, Ghali P, Deschenes M, Wong P. Hepatitis B and the infected health care worker: public safety at what cost? Can J Gastroenterol 2012;26:257–60.