

PREVENTING DISEASE THROUGH A HEALTHIER AND SAFER WORKPLACE

J Wolf, A Prüss-Ustün, I Ivanov, S Mudgal, C Corvalán, R Bos, M Neira



**World Health
Organization**

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CONTENTS

ACKNOWLEDGEMENTS	v
ACRONYMS AND ABBREVIATIONS	vi
EXECUTIVE SUMMARY	vii
INTRODUCTION	1
METHODS	3
Synthesis of disease burden	3
Review of interventions	3
OCCUPATIONAL RISKS BY DISEASE	5
Infectious and parasitic diseases	5
Respiratory infections	5
Intestinal infections	6
Malaria	7
Schistosomiasis	7
Chagas disease	9
Lymphatic filariasis	10
Onchocerciasis	10
Leishmaniasis	11
Dengue	11
Japanese encephalitis	12
HIV/AIDS	13
Sexually transmitted diseases	16
Hepatitis B and C	17
Tuberculosis	18
Other infectious and parasitic diseases	19
Noncommunicable diseases	20
Cancers	20
Mental, behavioural and neurological disorders	24
Cataracts	27
Hearing loss	28
Ischaemic heart disease	29
Stroke	30
Chronic obstructive pulmonary disease	32
Asthma	33
Pneumoconiosis	35
Musculoskeletal diseases	36
Neonatal conditions	37
Congenital anomalies	39
Occupational skin diseases	40
Other noncommunicable diseases	40

Risks factors for noncommunicable diseases from other areas but related to the work environment	42
Overweight and obesity	42
Physical inactivity	43
Unintentional injuries	44
Road traffic accidents	44
Unintentional poisonings	45
Falls	46
Fires, heat and hot substances	47
Drownings	48
Other unintentional injuries	49
Intentional injuries	50
Self-harm	50
Interpersonal violence	51
DISCUSSION	53
The workplace, health and the Sustainable Development Goals	56
CONCLUSIONS: TOWARDS HEALTHIER AND SAFER WORKPLACES	59
Key findings	59
Reducing the burden of unhealthy workplaces	60
REFERENCES	61
ANNEX	76
Methods: Estimating the occupational burden of disease	76
What is meant by the population attributable fraction of a risk factor?	76
Calculation of population attributable fractions	76
Estimating the population attributable fraction	77
Estimating the burden of disease attributable to the environment	79
Estimating uncertainties	79
Table A1. Examples of interventions for worker protection	80
Table A2. Deaths attributable to occupation, by region, 2015	82
Table A3. DALYs attributable to occupation, by region, 2015	84
PHOTO CREDITS	86

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ACRONYMS AND ABBREVIATIONS

BMI	body mass index
CI	confidence interval
CMDLD	coal mine dust lung diseases
COPD	chronic obstructive pulmonary disease
CRA	comparative risk assessment
DALY	disability-adjusted life year
GBD	global burden of disease
HBV	hepatitis B virus
HCV	hepatitis C virus
HIV	human immunodeficiency virus
IARC	International Agency for Research on Cancer
IHD	ischaemic heart disease
MeSH	medical subject headings
OSHA	Occupational Safety and Health Administration (United States Department of Labor)
PAF	population attributable fraction
PCB	polychlorinated biphenyl
PEP	post-exposure prophylaxis
PPE	personal protective equipment
PrEP	pre-exposure prophylaxis
STDs	sexually transmitted diseases
REACH	Regulation, Evaluation, Authorisation and Restriction of Chemicals (European Union)
SDGs	Sustainable Development Goals
TB	tuberculosis
UEMSD	upper extremity musculoskeletal disorders
UV	ultraviolet
UVGI	ultraviolet germicidal irradiation

EXECUTIVE SUMMARY

This assessment is a comprehensive report combining: a) the key evidence linking diseases and injuries to occupational risks; b) a quantitative assessment of the disease burden attributable to selected occupational risks; and c) a compilation of general interventions and selected examples of occupational and environmental interventions that successfully improve health.

This study estimates that in 2015, more than 1.2 million deaths globally were attributable to occupational risks, which represent 2.1% of all deaths in the general population. When accounting for both deaths and disability, the fraction of the global disease burden in the general population due to occupation amounts to 2.7%. Noncommunicable diseases contribute 70%, injuries 22% and infectious diseases 8% to the total disease burden from occupational risks. Low- and middle-income countries are disproportionately affected by occupational death and disease.

This study provides an approximate estimate of how much disease can be prevented by reducing occupational risks to health. The analysis uses a combination of approaches with a clear focus on comparative risk assessment methods, which apply detailed exposure and exposure-risk information. Of the 1.2 million deaths attributable to occupation, 1.1 million (90%) were estimated using comparative risk assessment methods, and the remaining using more limited epidemiological data and expert opinion. While the evidence has shown that many diseases are caused by occupational risks to health, to date, only a limited number of those could be quantified, suggesting that the disease burden from occupational risks presented in this report remains a conservative estimate.

This assessment summarizes extensive information on interventions to reduce the burden of disease due to occupation. It lists general interventions by disease or injury as well as selected examples of occupational and environmental interventions from the epidemiological literature. Occupational risks, in this study, include physical, chemical, biological and psychosocial risks, working conditions and the built environments of workplaces.



Truck flattening household rubbish on a landfill waste site.

INTRODUCTION

After the home environment, the workplace is the place where adults spend most of their time. During that time, they may experience diverse, often high-level, exposures, with subsequent health effects, which could be avoided. These exposures include both occupation-specific and non-specific exposures.

A large fraction of the population is affected by health conditions at their workplaces. The global proportion of the population (ages 15+) that was economically active in 2017 is estimated at 62% (ILO, 2017). Workplaces with a high risk for work-related disease and injury include mining, construction, agriculture and manufacturing. However, specific occupational groups might be at particular risk from specific diseases, for example, office workers might be at increased risk of stress and musculoskeletal diseases; health care workers of overexertion and infections; and cleaners of chemical exposures (Perry & Hu, 2010). The 60th World Health Assembly 2007 endorsed the global plan of action on workers' health 2008–2017 and urged Member States, among others, to work towards full coverage with essential interventions and basic occupational health services (WHO, 2007c).

This report provides an overview of the burden of disease that could be prevented through decreasing work-related risks to health, and documented preventive action. It thereby identifies and evaluates steps and priorities for targeted action towards healthier and safer workplaces, which play a crucial role in protecting people's health. It is based on the best available evidence for the selected diseases and injuries and their links to the workplace. Where feasible, the study uses comprehensive and the most accurate estimates available from comparative risk assessment (CRA) methods (WHO, 2004a; Forouzanfar et al, 2015), which apply detailed exposure and relative risk estimates assessing the burden of disease by region, country and age group. However, these assessments remain limited in terms of the range of occupational risks assessed and are therefore complemented by extensive literature reviews, approximate epidemiological estimates and standardized surveys of expert opinion. Focusing on modifiable occupational risks, i.e. those reasonably amenable to management or change given current knowledge and technology, resources and social acceptability, the current study examines "how much" such factors affect various diseases and injuries – both in terms of premature mortality and of overall disease burden as measured by disability-adjusted life years (DALYs), a weighted measure of death and disability.

A range of strategies for preventing occupational disease burden exists, and is awaiting broader implementation. In addition to outlining major links between occupational exposures and workers' health and a synthesis of health impacts, this report compiles general intervention guidance (following each disease section and in Table A1 of the Annex) as well as selected examples of occupational and environmental interventions from the epidemiological literature.



METHODS

Occupational risks, in this study, include physical, chemical, biological and psychosocial risks, working conditions and the built environment of workplaces.

SYNTHESIS OF DISEASE BURDEN

The quantification of health impacts from occupational exposures is based on a systematic literature review of exposure to occupational risk factors and links between the respective exposure and disease or injury. The population attributable fraction (PAF) is the proportional reduction in death or disease that would occur if exposure to a risk was removed or maximally reduced to an alternative level. PAFs have been retrieved from various sources, and applied to the WHO database of burden of disease, giving estimates for 2000–2015, by country, age and sex group (WHO, 2016b). The preferred sources for PAFs include global estimates of population impacts based on CRA (IHME, 2016), followed by estimates based on more limited epidemiological data and expert opinion from standardized surveys.

The chapters contained in this document are adaptations and extensions of a previously published report on the burden of disease from environmental and occupational risks (Prüss-Ustün et al, 2016). The annex of this report contains information on the methods applied in this document. More detailed information can be found in Prüss-Ustün et al (2016).

In this document, PAFs of disease burden are presented in DALYs, which are a weighted measure of deaths and disability or, if specifically mentioned, of premature mortality. PAFs refer to the proportion of occupational or work-related disease burden relative to the disease burden in the total general population.

REVIEW OF INTERVENTIONS

In occupational health the approach to prevention usually follows a prevention hierarchy that goes from the most to the least effective or desirable intervention (CDC, 2016):

1. elimination of the hazard;
2. substitution of the hazard;
3. engineering controls, i.e. use of mechanical or technical measures such as enclosure, ventilation and workplace design to minimize exposure;
4. administrative controls, i.e. changes to the way people work to minimize exposure; and
5. personal protective equipment (PPE).

To compile examples of occupational or environmental interventions by disease, a literature search was performed in PubMed and Google Scholar, complemented by searching the Cochrane Library and websites of specific Cochrane groups (Cochrane Work Group and Cochrane Health and Safety Group). A search strategy by disease was developed including both key words and medical subject headings (MeSH) terms. Additionally, websites of national and international institutes for health and safety were screened for general intervention guidance. Literature from January 2000 to May 2016 was searched for inclusion in this review.



Traditional brick factory (Tozeur, southern Tunisia).

OCCUPATIONAL RISKS BY DISEASE

In this chapter, diseases or disease groups and their links to occupation are presented in individual sections. If the burden of disease has been quantified for a specific disease or disease group, it is listed below the title (otherwise “no GBD estimate” is added).

INFECTIOUS AND PARASITIC DISEASES

Respiratory infections

No GBD estimate

Overview: Lower respiratory infections include pneumonia, bronchitis and bronchiolitis, causing more than 3 million deaths in 2015 (WHO, 2017k). Pneumonia is an infection of the lung which can be caused by exposure to a number of infectious agents, including viruses, bacteria and fungi (WHO, 2016c).

Occupation-specific: Though the highest disease burden from lower respiratory infections is found in children, respiratory infections have been associated with several occupational exposures in adults. Health care workers are at increased risk of respiratory infections, especially when performing high-risk procedures (Tran et al, 2012; Macintyre et al, 2014). Occupational exposure to dusts, gases, fumes, chemicals, or sudden temperature changes and psychosocial stress in the workplace were identified as risk factors for respiratory infections (Hnizdo & Storey, 2010; Runeson-Broberg & Norbäck, 2014; Almirall et al, 2015). Exposure to occupational fumes additionally increased mortality from respiratory infections (Palmer et al, 2009; Torén et al, 2011; Vehmas et al, 2012). Occupational risks for upper respiratory infections, such as pharyngitis, laryngitis or sinusitis, are less well documented. Upper airway infections, such as occupational laryngitis or occupational rhinitis, a disease of emerging relevance due to its link with asthma development, were associated with exposure to several irritants in the workplace (Williams, 2002; Moscato et al, 2011). Teachers have been shown to be at greater risk of laryngitis and other voice disorders than other professions, probably due to higher vocal loading (Sala et al, 2001).

Tuberculosis is treated in a separate section.

Examples of interventions

Occupations at increased risk include health care workers (WHO, 2014b).

- Engineering controls, such as adequately ventilated single rooms for performing aerosol-generating procedures and ultraviolet germicidal irradiation (UVGI) for disinfection of air.
- Administrative controls, such as clinical triage for early identification of patients with respiratory infections, spatial separation between patients and others, patient cohorting if possible, influenza vaccination for health care workers and respiratory hygiene of patients with respiratory infections.
- PPE according to the procedure and suspected pathogen.

These recommendations should always be supplemented with standard precautions such as hand hygiene.

Examples of occupational or environmental interventions from the epidemiological literature

Engineering controls, such as ventilation; administrative controls, such as early treatment and isolation of patients and vaccination of health care workers; and PPE and personal hygiene can successfully prevent respiratory infections such as influenza in health care workers (Trajman & Menzies, 2010; Yang et al, 2011).

Intestinal infections

No GBD estimate

Overview: In this section, intestinal infections comprise diarrhoeal diseases from different, mainly faecal-oral pathogens and intestinal nematode infections. Diarrhoeal diseases are one of the main contributors to global child mortality (WHO, 2017k). The predominant route of transmission depends on the pathogen, local infrastructure (e.g. whether the population has access to appropriate sanitation and safe water) and human behaviour. Intestinal nematode infections, which comprise ascariasis, trichuriasis and ancylostomiasis/necatoriasis (roundworm, whipworm and hookworm disease, respectively), are intestinal infections caused by soil-transmitted helminths. About 1.5 billion people worldwide are infected with soil-transmitted helminths (WHO, 2017z). Transmission does not occur from person to person or from fresh faeces but via soil contaminated with human excreta containing infectious eggs or larvae.

Occupation-specific: The rapidly expanding practice of wastewater use in agriculture, particularly in peri-urban areas, increasingly contributes to the transmission of gastrointestinal diseases, such as diarrhoea, giardiasis and intestinal helminth infections among agricultural workers, communities practising this form of agriculture and consumers of the resulting produce (Srikanth & Naik, 2004; Ensink et al, 2005; Trang et al, 2007; Pham-Duc et al, 2013; 2014). Currently, little is known about the relative importance of this pathway. WHO has published guidelines proposing integrated risk assessment and management to prevent transmission and the associated adverse health impacts (WHO, 2006a). Between 4 and 20 million hectares of land were estimated to be under wastewater irrigation in 2010 (Drechsel et al, 2010). Other occupational groups at risk of diarrhoea and gastrointestinal disease are those that need to travel from low- to high-risk areas, such as military personnel (Connor et al, 2012) and business people (Patel, 2011).

Examples of interventions

Occupations at increased risk include agricultural workers and miners in endemic settings (WHO, 2006a; 2017z).

- Vector control and reduced vector contact, for example, through safe drinking-water and sanitation facilities at the workplace.
- Periodic medicinal treatment (albendazole or mebendazole) without previous individual diagnosis.
- Worker education and training.
- PPE.



Intestinal infections can be reduced through safe drinking-water and sanitation facilities in the workplace, safe handling of wastewater, education and PPE.

Malaria

No GBD estimate

Overview: Malaria is the most important vector-borne disease globally, causing many deaths in children under five (WHO, 2017p). It is caused by species of protozoan parasites belonging to the genus *Plasmodium*, which are transmitted by the bites of infected *Anopheles* mosquitoes. The larval stages of anopheline mosquitoes occur in a wide range of habitats, but most species share a preference for clean, unpolluted, stagnant or slowly moving fresh water (Muir, 1988). Malaria is a life-threatening disease. In 2015, it caused an estimated 439 000 deaths, mostly among African children (WHO, 2017k; 2017p).

Occupation-specific: Some occupations increase the risk of contracting malaria. Construction (Shivalli et al, 2016) and agricultural sites (Naidoo et al, 2011) offer breeding possibilities for mosquitoes and workers spend much time in these places. Occupations that require high mobility, such as workers travelling from low- to high-risk areas, e.g. migrant farm workers (Schicker et al, 2015), military personnel (Ajili et al, 2013) and expatriates (Rathnam et al, 2007; Roukens et al, 2008), might also lead to increased malaria risk (Patel, 2011). Sporadic occupational malaria was also observed after accidental blood exposure in health care workers (Tarantola et al, 2005).

Examples of interventions

Occupations at increased risk include agricultural and migrant workers in endemic settings.

- Vector control through environmental management, such as intermittent irrigation, and safe sanitation, water management and drainage.
- Worker education and training.
- PPE, such as mosquito nets, insect repellents and protective clothing (WHO, 2006b).

Examples of occupational or environmental interventions from the epidemiological literature

- Environmental management was shown to be an effective strategy in reducing malaria; this might be especially promising in agricultural settings (Keiser, Singer et al, 2005).
- Long-lasting permethrin-impregnated clothing can protect outdoor workers against mosquito bites (Londono-Renteria et al, 2015).

Schistosomiasis

No GBD estimate

Overview: Schistosomiasis is a disease caused by infection with trematodes (blood flukes), parasitic worms of the genus *Schistosoma*, living in the veins that drain the intestines or the urinary tract. *Schistosoma* flukes have a complex lifecycle which includes the obligatory passage through species of aquatic or amphibious snails. Transmission occurs through direct human contact with excreta-contaminated water containing free-swimming larval forms shed by the intermediate host snails, which then penetrate human skin (WHO, 2017y). The damage caused to intestinal (by *S. mansoni*, *S. japonicum*) or urogenital tissues (by *S. haematobium*) results from the large quantities of eggs produced by the flukes, which work their way through these tissues and from the associated immune reaction of the host. Left untreated, the disease can lead to long-term, irreversible health effects, including liver and kidney damage, infertility or bladder cancer (Heymann, 2008; WHO, 2017y). More than 200 million people required preventive treatment for schistosomiasis in 2016 (WHO, 2017y).

Examples of interventions

Occupations at increased risk include fishermen, agricultural and irrigation workers in endemic settings (WHO, 2015d; 2017y).

- Vector control through environmental management.
- Access to safe sanitation.
- Preventive chemotherapy with praziquantel.
- Worker education and training.

Occupation-specific: Occupations with frequent water contact, such as fishermen (Li et al, 2003) and farm workers in irrigated agricultural production systems (Matthys et al, 2007), are at risk. Areas with a lack of adequate sanitation and ecological conditions favouring the propagation of intermediate host snails result in increased risk of contracting the disease (Steinmann et al, 2006). Also the practice of using human waste as agricultural fertilizer has been shown to contribute to schistosomiasis infections (Carlton et al, 2015).

Examples of occupational or environmental interventions from the epidemiological literature

- Environmental management integrated with agricultural activities, water resources development and forestry projects has been shown to be effective in snail control (Liu et al, 2008; Zhou et al, 2011). Environmental management has successfully achieved the interruption of transmission in most regions in China, and led to eradication of the disease in Japan (Ebisawa, 1998; Zhou et al, 2005b).
- The rehabilitation of the Mushandike irrigation scheme in Zimbabwe in the 1980s included self-draining hydraulic structures and carefully sloped irrigation and drainage canals to prevent snail infestation; elimination of high-risk infrastructure such as duckbill weirs; improved management of night storage ponds; and the deployment of latrines in a grid pattern in fields to avoid contamination of water bodies. This led to low schistosomiasis prevalence rates after 10 years, while control schemes without the environmental measures maintained consistently higher rates (Chimbari, 2012).
- In China, farmland consolidation and replacing cattle with agricultural machinery effectively reduced *Schistosoma* infections in humans (Xu et al, 2013).
- In China, a comprehensive *S. japonicum* control programme combining interventions at the workplace and in people's homes, including environmental modification for the management of water resources, health education to reduce human contact with infected water, and installation of water supply and sanitation facilities, and chemotherapy of humans and livestock, effectively reduced *Schistosoma* prevalence in humans, eliminated infection in livestock and considerably reduced the size of the area where infected snails were found (Hong et al, 2011).
- Another comprehensive schistosomiasis control programme in Chinese villages – removing cattle from snail-infested grasslands, providing farmers with mechanized equipment, providing sanitation at the workplace (for fishermen and boatmen), and tap water and improved sanitation at home, and health education targeting fishermen and boatmen – reduced *Schistosoma* infection rates in humans from 11.3% and 4.0% to 0.7% and 0.9% in villages 1 and 2, respectively. The same intervention, furthermore, reduced soil-transmitted helminth infections (Wang et al, 2009). Economic evaluations of this programme showed it to be more cost-beneficial than a health sector-confined programme based on diagnosis and treatment of humans and cattle, health education and focal mollusciciding (Lin et al, 2009; Yu et al, 2013).
- An evaluation of the integrated Chinese national schistosomiasis control programme over eight years concluded that US\$ 6.20 was gained for every US\$ 1 spent (Zhou et al, 2005a).
- In China, health education and protective skills training directed at construction workers in the Poyang Lake area successfully reduced *Schistosoma* infection and increased protective behaviour (Yang et al, 2012; Wu et al, 2013).
- The prevalence of *S. mansoni* infection in Sudanese canal cleaners reduced after an intervention that shifted work from midday to early morning compared with a control group with normal working schedules (Tameim et al, 1985).

Chagas disease

No GBD estimate

Overview: Between 6 and 7 million people are estimated to be infected with *Trypanosoma cruzi*, the protozoan parasite which causes Chagas disease. Around 30–40% of people with chronic Chagas infections develop chronic, potentially life-threatening alterations of the heart, nervous system or gastrointestinal system (WHO, 2017e). The parasite is transmitted by various species of Mexican and Central and South American triatomine bugs (Moncayo & Silveira, 2009), which have a range of resting and breeding places in and around houses.

No vaccine to protect against *T. cruzi* is currently available. Drugs exist to treat Chagas disease effectively at the earliest onset and acute phase. For lack of distinct clinical symptoms, this phase often passes unnoticed. Successful treatment in the chronic phase remains limited.



Workers' settlement – housing improvements in poor settlements can reduce the risk of Chagas infection.

Examples of interventions

Occupations at increased risk include agricultural workers, migrant workers, workers residing and working in poor settlements in endemic settings and laboratory personnel (handling Chagas infected material) (WHO, undated; Bos, 1987; Coutinho et al, 2014; WHO, 2015d; 2017e).

- Vector control through environmental management such as improved animal management.
- Worker education and training.
- Housing and food hygiene.
- PPE – mosquito nets and protective clothing/equipment, including laboratory coats, gloves, face masks, caps and glasses.

Examples of occupational or environmental interventions from the epidemiological literature

- Housing interventions, such as wall plastering and improved household hygiene, were effective in Chagas vector control (Zeledón & Rojas, 2006; Zeledón et al, 2008; Monroy et al, 2009).

Lymphatic filariasis

No GBD estimate

Overview: Lymphatic filariasis is caused by infection with one of three species of parasitic roundworms of the family Filarioidea: *Wuchereria bancrofti* (responsible for 90% of cases), *Brugia malayi* (responsible for most of the remaining cases) and *B. timori* (with a distribution limited to the Lesser Sunda Islands of Indonesia and Timor-Leste). Over 850 million people in 52 mainly South-East Asian and African countries are living in areas that require preventive chemotherapy to stop the spread of the infection (WHO, 2017o). The adult worms lodge in lymphatic vessels where they cause damage and disrupt the immune system, later in life leading to lymphedema, abnormal swelling of extremities or, in men, of the scrotum. The infection can be at the root of severe disability in later life. Adult worms shed large quantities of microfilariae into their human hosts' blood, which are then picked up by mosquitoes. Transmission occurs by the bite of mosquitoes harbouring the worms' larvae.

Occupation-specific: Workplaces, such as farms, can offer favourable environmental conditions for mosquito breeding (Erlanger et al, 2005) and accordingly high prevalence of lymphatic filariasis has been observed in certain occupational groups (Khan et al, 2015).

Examples of interventions

Occupations at increased risk include agricultural workers in endemic settings (WHO, 2015d, 2017o).

- Vector control through for example safe sanitation and water management.
- PPE, such as mosquito nets and protective clothing.

Onchocerciasis

No GBD estimate

Overview: Onchocerciasis is a disease caused by the parasitic filarial worm *Onchocerca volvulus*. It is the second most important cause of blindness due to infection, after trachoma. More than 99% of people infected live in 31 West and Central African countries; some foci of the disease also exist in Latin America and Yemen. Its distribution is closely linked to the distribution of its vectors – blackflies of the genus *Simulium*. Repeated exposure to infective bites in endemic areas leads to high parasite loads, and symptoms including severe itching, disfiguring skin conditions and visual impairment, which may lead to permanent blindness (WHO, 2017†).

Occupation-specific: Workers who spend much of their time outdoors might be of increased risk of contracting onchocerciasis and high prevalence was observed, for example, in farmers and farm workers (Anosike et al, 2001; Hailu et al, 2002; Mengistu et al, 2002; Dozie et al, 2004).

Examples of interventions

Occupations at increased risk include agricultural workers in endemic settings (CDC, 2013; WHO, 2017t).

- Vector control through environmental management.
- Community-directed treatment with ivermectin.
- PPE, such as protective clothing and insect repellents.

Leishmaniasis

No GBD estimate

Overview: Leishmaniasis is an infectious parasitic disease caused by protozoans of the genus *Leishmania*. It comes to expression in a continuum of species-related clinical manifestations ranging from muco-cutaneous and cutaneous (affecting mucus membranes and the skin) to visceral (affecting internal organs). The parasite is transmitted by different species of phlebotomine sandflies. Left untreated, the visceral form of the disease is fatal. WHO estimates that up to one million new cases and up to 30 000 deaths occur each year (WHO, 2017n).

Occupation-specific: Blood meal analyses have shown sandflies to be opportunistic, taking blood meals from a range of vertebrates; domestic animals kept close to or in the house will contribute to maintaining a higher population density of vectors, for example in Tunisia (Jaouadi et al, 2013). Moving domestic animals away from human habitation may, in the short term, lead to increased biting of humans, but may, in the longer term, result in transmission reduction. This may be especially important for Africa and Asia where, in the main, the vector is thought to breed close to houses. Migrant agricultural labourers without adequate housing are particularly at risk and should rely on personal protection measures, such as sleeping under mosquito nets (Argaw et al, 2013). Professions, such as military personnel, that involve occupational travel to high-risk areas, also pose an increased risk of contracting the disease (Oré et al, 2015).

Examples of interventions

Occupations at increased risk include agricultural workers in endemic settings (WHO, 2017n).

- Vector control through environmental management.
- Worker education and training.
- PPE.

Dengue

No GBD estimate

Overview: Dengue fever is the most rapidly spreading mosquito-borne viral disease in the world, with about half of the world's population now at risk for dengue infection (WHO, 2017g). There is considerable underreporting and misclassification in the surveillance of dengue cases. One estimate indicates 390 million (284–528 million) dengue infections per year, of which 96 million (67–136 million) presented with clinical manifestations (Bhatt et al, 2013). Another prevalence study estimates that 3.9 billion people, in 128 countries, are at risk of infection with dengue viruses (Brady et al, 2012). Member States in three WHO regions reported 3.2 million dengue cases in 2015, an increase of one million cases compared with 2010 (WHO, 2017g).

Examples of interventions

Occupations at increased risk include agricultural and migrant workers in endemic settings (WHO, 2017g).

- Vector control through environmental management, disposing waste properly, removing artificial habitats, covering, emptying and cleaning of domestic water storage containers.
- PPE.

The vector breeds in clean, artificial and sometimes natural water collections close to human dwellings. Strategies to prevent dengue fever therefore focus on bringing down population densities of the mosquito vectors (*Aedes aegypti* and *Aedes albopictus*) through source reduction and/or minimizing human/vector contact. The latter is a challenge as these mosquitoes are daytime biters, limiting the practical use of mosquito nets.

Occupation-specific: Similar to malaria, some occupations where workers spend much time outdoors and workplaces that offer breeding possibilities for mosquitoes (such as agriculture and construction) might increase the risk of contracting dengue (Seet et al, 2005). Additionally, health care workers treating patients with dengue might occasionally contract the disease via needlestick injuries (Morgan et al, 2015; Ohnishi, 2015). Occupations requiring travel to endemic areas also pose an increased risk of infection with the dengue virus (Sebeny & Chretien, 2013; Visser & Edwards, 2013; Salyer et al, 2014).

Examples of occupational or environmental interventions from the epidemiological literature

- In Thailand, an occupational health programme to reduce dengue incidence in health care workers, including restricting water sources, applying insecticides on standing water sources and on hospital grounds, and ongoing active disease surveillance, significantly reduced dengue infections in this occupational group (Apisarnthanarak & Mundy, 2009).
- In Taiwan, China, distribution of fine nets to farmers to cover their water containers used for irrigation significantly reduced the dengue vector *Aedes aegypti* (Chuang et al, 2009).
- Long-lasting permethrin-impregnated clothing can protect outdoor workers against mosquito bites (Londono-Renteria et al, 2015).

Japanese encephalitis

No GBD estimate

Overview: Japanese encephalitis virus, a flavivirus related to West Nile virus and Saint Louis encephalitis virus, is the leading cause of viral encephalitis in South, South-East and East Asia (WHO, 2015c). The annual incidence of clinical disease varies both across and within countries, ranging from <10 to >100 per 100 000 population. A literature review estimates nearly 68 000 clinical cases globally each year, with up to 20 400 deaths (Campbell et al, 2011). It primarily affects children. Most adults in endemic countries have natural immunity after childhood infection, but individuals of any age may be affected. It is a vaccine-preventable disease, however, in many countries the capacity to deliver costly vaccination programmes in rural areas remains limited.

Although symptomatic Japanese encephalitis is rare, the case-fatality rate among those with encephalitis can be as high as 30% (WHO, 2015c). Of those who survive, 30–50% suffer important long-term neurological sequelae (conditions resulting from having had the disease). There is considerable misdiagnosis and under reporting, and the number of real cases is assumed to be significantly higher (Tarantola et al, 2014).

Occupation-specific: The Japanese encephalitis virus has well-defined links to specific ecologies; mainly irrigated rice

Examples of interventions

Occupations at increased risk include agricultural workers in endemic settings (Rozendaal, 1997; Keiser, Maltese et al, 2005; Erlanger et al, 2009; WHO, 2015c).

- Vector control through environmental management of irrigated rice production systems and integrated vector management.
- Vaccination for people and possibly pigs.
- Improved pig husbandry such as mosquito-proofing of pigsties.
- PPE, such as mosquito nets, insect repellents and protective clothing.

production systems. People working in agriculture in affected areas are therefore at particular risk. The natural hosts of the virus are ardeid birds (herons and egrets living in an aquatic environment). Pigs are the main amplifying host. The mosquito vectors of the Japanese encephalitis virus (*Culex tritaenorrhynchus*, *C. vishnui* and the suspected vector *C. gelidus*) breed by preference in irrigated rice fields and in natural wetland areas; these *Culex* species are zoophilic (i.e. they prefer taking their blood meals from animals rather than humans). In special conditions, however, mosquito populations may build up so rapidly that the virus transmission spills over into the human community. Such situations include the flooding of large areas of rice fields at the time of transplantation of the rice plants, or when there is a heavy onset of the rainy season. As the vector is usually exposed to pesticides in rice field, multiple pesticide resistance is common (Leong et al, 2014; Jeffries & Walker, 2015).



People working in irrigated rice production systems are at particular risk of Japanese encephalitis, which can be severe and cause death.

By and large, the distribution of Japanese encephalitis is limited mainly to rural or peri-urban areas and has been associated with climate, agricultural development and rice cultivation (WHO, 2015c). As the demand for rice and pork is likely to grow substantially in the future, there is concern that the frequency and intensity of outbreaks will increase along with the risk of exposure to larger working populations.

HIV/AIDS

8.2% attributable to occupational risks (epidemiological estimates)

Overview: In 2016, around 37 million people were living with the human immunodeficiency virus (HIV). Large regional differences remain. Sub-Saharan Africa is most affected but other regions, such as the Caribbean, Eastern Europe and Asia, have high numbers of infected people (UNAIDS, 2017).

Occupation-specific: Certain occupational groups are at increased risk of acquiring or transmitting HIV. These include commercial sex workers, health care workers who may be infected by needlestick injuries or other exposures, and workers who spend part of the year away from their families (referred to as workers at “intermediate risk”). Female sex workers are 13.5 times more likely to be HIV infected than the general female adult population (Baral et al, 2012; Kerrigan et al, 2013). Worldwide, a significant percentage of the female population is involved in the commercial sex industry. A global review estimated that female sex workers present 0.4–4.3% of the female population in urban areas in sub-Saharan Africa, 0.2–2.6% in Asia and 0.2–7.4% in Latin America (Vandepitte et al, 2006). The global proportion of health care workers in the



Female sex workers are 13 times more likely to be HIV-infected than the general female adult population. Other occupations at risk are health care workers and workers who spend part of the year away from their families.

general population is estimated to be 0.6% and the overall fraction of HIV infection acquired through a needlestick injury among this occupational group is 4.4% (Prüss-Ustün et al, 2005).

Workers at intermediate risk mainly include the uniformed workforce (e.g. policemen), the military, miners, truck drivers, migrant construction workers, seafarers and fishermen. Because many in these sectors live away from their families part of the year, they are more likely to have sex with sex workers and other occasional partners, and thus be at increased risk of infecting themselves and their partners on return home (UNAIDS & WHO, 2009). It has been shown that these occupational groups are generally more vulnerable to HIV infections compared with the general population (Kissling et al, 2005; Fraser et al, 2008). The intermediate risk group is around 3% of the total population globally, but its risk is relatively lower than that of commercial sex workers.

The fraction of HIV/AIDS attributable to occupation can be roughly estimated by comparing the adult prevalence rate in the general population with that of commercial sex workers (Prüss-Ustün et al, 2013), or workers at intermediate risk (after accounting for competing risks, such as intravenous drug use). In adults, for example, the prevalence of HIV in female sex workers was estimated to be 12–29 times higher than in the general female population, depending on the region (Baral et al, 2012). Around 15% of HIV in the general female adult population is thought to be attributable to female sex work (Prüss-Ustün et al, 2013). Information on male sex workers was too scarce to make an estimate. In 2005 it was estimated that about 0.02% of the global HIV/AIDS burden was caused by percutaneous injuries to health care workers (Prüss-Ustün et al, 2005).

Based on an approximate estimation using available epidemiological data (see Annex and Prüss-Ustün et al, 2016 for details), occupational causes accounted for 8.2% (6.0–10.5%) of the HIV disease burden globally, causing about 93 000 deaths annually (calculations based on epidemiological data, see Annex and Prüss-Ustün et al, 2016). This estimate only covers HIV transmission to sex workers and workers at intermediate risk (truck drivers, fishermen, the military etc.), but infected workers may, in turn, infect members of the general population. In certain countries, the HIV epidemic may even be largely driven by commercial sex activities or spread predominantly by truck drivers and other clients. The impact of prevention that is targeted to certain occupational groups may therefore be more far reaching than simply improving workers' health.

Examples of interventions

Occupations at increased risk include sex workers, the uniformed workforce (e.g. policemen), the military, miners, truck drivers, migrant workers, seafarers and fishermen.

WHO recommends a comprehensive package of essential health sector interventions for HIV prevention, diagnosis, treatment and care (WHO, 2017v). Interventions for HIV prevention in sex workers and other key populations include:

- Pre-exposure prophylaxis (PrEP) offered to workers at substantial risk of HIV infection.
- Post-exposure prophylaxis (PEP).
- Harm reduction interventions for substance use such as needle and syringe programmes, opioid substitution therapy and naloxone distribution.
- Worker education and training.
- Correct and consistent use of condoms with condom-compatible lubricants.

Occupations at increased risk include health care workers (WHO, ILO and UNAIDS, 2010):

- PEP.
- Worker education and training.
- PPE and safe needle technology.



Temporary labour camp at a construction site. Workers that live away from their families part of the year are at increased risk of HIV/AIDS.

Examples of occupational or environmental interventions from the epidemiological literature

- Voluntary counselling and testing at the workplace increased HIV testing and lowered self-reported HIV and other sexually transmitted diseases (STDs) incidence. Furthermore, educational interventions at the workplace decreased STDs, unprotected sex and sex with commercial sex workers (Ojo et al, 2011).
- Behavioural and educational interventions were associated with reduced risky sexual behaviour in migrant workers, truck drivers and the military (Essien et al, 2011; Lau & Tsui, 2012; Sánchez et al, 2013; Zhu et al, 2014).

Sex workers

- Community empowerment approaches to addressing HIV among sex workers are effective in decreasing HIV and other sexually transmitted infections and increasing consistent condom use (Kerrigan et al, 2015).
- It was estimated that decriminalization of sex workers could avert 33–46% of new HIV infections in sex workers and their clients, e.g. through creating safer work environments (Beyrer et al, 2015).
- Cambodia and Thailand, countries with an early and rapid rise of the HIV epidemic, implemented highly successful prevention programmes that were associated with an increase in condom use in the commercial sex sector to around 90% (Rojanapithayakorn & Hanenberg, 1996; Ruxrungtham et al, 2004). This programme has since been implemented in many Asian countries (Rojanapithayakorn, 2006).
- Peer/community counselling and condom distribution among female sex workers are cost-effective interventions in South-East Asia and sub-Saharan Africa (Beyrer et al, 2015).
- Behavioural interventions were shown to effectively reduce HIV and the incidence of other STDs in sex workers and their clients (Wariki et al, 2012), to increase knowledge about HIV-transmission in sex workers and their clients (Ota et al, 2011) and to increase condom use and HIV-testing in sex workers (Chow et al, 2015).
- The cost per HIV infection averted for community empowerment-based comprehensive HIV prevention in sex workers depends on the HIV prevalence. It amounts to US\$ 1 990 in the Ukraine, US\$ 3 813 in Kenya, US\$ 66 128 in Thailand and US\$ 32 773 in Brazil (Kerrigan et al, 2013).
- The cost per client for the community-based, comprehensive HIV prevention intervention among sex workers ranges from US\$ 102–184. When removing the averted HIV-related medical costs, those costs are significantly reduced (Kerrigan et al, 2013).

Health care workers

- Effective measures to prevent infections from occupational exposure of health care workers to blood include eliminating unnecessary injections, implementing universal precautions, eliminating needle recapping and disposing needles into a sharps container immediately after use, use of safer devices such as needles that sheath or retract after use, provision and use of PPE, and training workers in the risks and prevention of transmission (Wilburn & Eijkemans, 2004).
- Workplace interventions showed positive outcomes for HIV and tuberculosis diagnosis and treatment in health care workers, such as increased uptake and adherence to treatment, better clinical outcomes and less risky behaviour (Yassi et al, 2013).
- Wearing two instead of one pair of gloves reduces percutaneous exposure incidents (e.g. needlestick injuries), and thereby the risk of bloodborne infections such as HIV and hepatitis B and C during surgery (Mischke et al, 2014). Blunt versus sharp suture needles reduce the risk of exposure to blood and bodily fluids for surgeons and their assistants (Saarto et al, 2011). Devices, such as safe blood collection systems and intravenous systems, might decrease needlestick injuries in health care personnel (Lavoie et al, 2014).

Sexually transmitted diseases

3.0% attributable to occupational risks (epidemiological estimates)

Overview: Each year, an estimated 357 million people acquire chlamydia, gonorrhoea, syphilis or trichomoniasis (WHO, 2016d). Hepatitis B, hepatitis C and HIV/AIDS are covered in separate sections.

Occupation-specific: Workers in several occupations are at increased risk of infection. Sex workers, in particular, are at high risk for STDs compared with the general population (Cwikel et al, 2008; Zoni et al, 2013). Other groups of workers, including truck drivers, military, fishermen, miners, certain construction workers and migrant agricultural workers, are also at increased risk of infection because their work takes them away from home for extended periods of time and they are more likely to seek casual partners, particularly from among commercial sex workers (Kwena et al, 2010; Zhang et al, 2010; 2013; Goyal et al, 2012).

Although the transmission rates of STDs to sex workers and other workers at increased risk may be significant within the occupational group, such worker categories represent a relatively small fraction of the general population (typically 0.2–4% of female sex workers among female adults, depending on the region), and only about 3% of workers globally are at increased risk. The total PAF for the occupational disease burden, based on the main STDs except HIV/AIDS (syphilis, chlamydia, gonorrhoea etc.) was estimated to be 3% (1.5–6.1%) of the total population. These estimates are based on epidemiological data (see Annex and Prüss-Ustün et al, 2016 for additional information).

This estimate covers the transmission to workers, rather than infections to the general population by infected workers. Transmission to the general population from workers is potentially a major consequence of occupational transmission, and in some countries may even fuel the ongoing epidemic.

Interventions for preventing infections, or screening and treatment programmes, have been successful in certain occupational groups (Ross et al, 2006; MacDonald, 2013). Interventions against STDs are similar to many of those listed for HIV/AIDS.



Hepatitis B and C

- **Hepatitis B: 2.1% attributable to occupational risks (epidemiological estimates)**
- **Hepatitis C: 0.4% attributable to occupational risks (epidemiological estimates)**

Overview: Hepatitis B and C are viral liver infections that can become chronic and can lead to cirrhosis or liver cancer (WHO, 2017l; 2017m). The infections can be transmitted by exposure to infected blood or body fluids. More than one million people die every year from hepatitis B- and C-related liver diseases.

Occupation-specific: Certain occupational groups are at increased risk of infection with the hepatitis B (HBV) or C virus (HCV) at work, or because of their working and living conditions. Many of the occupational groups at risk are the same as those at risk for occupational HIV infection and STDs. The groups include commercial sex workers (Atkins & Nolan, 2005), workers exposed to percutaneous injuries with contaminated sharp objects (e.g. nurses, doctors, laboratory staff, waste workers) (Singh, 2009; Corrao et al, 2013) and workers at intermediate risk (e.g. migrant workers, members of the uniformed workforce, miners, truck drivers, fishermen) who spend time away from home and are more likely to seek the services of sex workers (Manjunath et al, 2002; Government of Kiribati & Secretariat of the Pacific Community, 2008; Pinho et al, 2011).

Although HBV is highly sexually transmissible, it is not always possible to dissociate this route of transmission from other means, for example injecting drug use, as studies of commercial sex workers have shown. Nevertheless, hepatitis B is generally more prevalent in commercial sex workers than in the general population in low- and middle-income countries (Camejo et al, 2003; Forbi et al, 2008; Zhang et al, 2014). The risk of sexual transmission of HCV between monogamous partners is extremely low, but is higher among men who have sex with men (Tohme & Holmberg, 2010).

It has been estimated that the PAFs for occupational HBV and HCV infections in health care workers are 0.3% of the global hepatitis C burden, corresponding to 16 400 HCV infections per year; and 0.3% of the global hepatitis B burden, corresponding to 65 600 HBV infections per year (Prüss-Ustün et al, 2005). Based on comparisons of prevalence in commercial female sex workers, workers at intermediate risk and the general population, it has been estimated that the total PAF for occupational HBV infections is 2.1% (0.6–4.2%) and 0.4% (0.3–0.6%) for occupational HCV. These estimates are based on epidemiological data (see Annex and Prüss-Ustün et al, 2016). In high-income countries, only infections of health care workers from sharps injuries were considered.

Interventions against sexually transmitted HBV and HCV are similar to those listed for HIV/AIDS.

Examples of interventions

Occupations at increased risk include health care workers (Schillie et al, 2013).

- Hepatitis B vaccination for all health care workers.
- Post-exposure management/prophylaxis.
- Worker education and training.
- PPE and safe needle technology.

Examples of occupational or environmental interventions from the epidemiological literature

- Hepatitis B vaccination significantly prevents hepatitis B events in health care workers (Chen & Gluud, 2005).
- Adequate hand washing, wearing gloves, gowns and masks, reducing the manipulation of sharps and using puncture-resistant containers for sharp disposal can prevent transmission of hepatitis in the health care setting (Askarian et al, 2011).
- Wearing two instead of one pair of gloves reduces percutaneous exposure incidents (e.g. needlestick injuries), and thereby the risk of bloodborne infections such as HIV, HBV and HCV during surgery (Mischke et al, 2014). Devices, such as safe blood collection systems and intravenous systems, might decrease needlestick injuries in health care personnel (Lavoie et al, 2014).



2.1% of all hepatitis C infections are related to occupation.

Tuberculosis

No GBD estimate

Overview: Tuberculosis (TB) is an infectious bacterial disease caused by *Mycobacterium tuberculosis*. The disease kills 1.7 million people per year, and over 95% of TB deaths occur in low- and middle-income countries (in 2016) (WHO, 2017aa). About one third of the world's population is infected with the latent TB bacteria, but in only a small fraction (up to 10%) will the disease progress to the active state. Different risk factors, such as crowding, malnutrition, household air pollution and second-hand tobacco smoke exposure, influence exposure to tuberculosis, risk of acquiring the infection or progression from latent tuberculosis infection to disease (Lönnroth et al, 2009; Leung et al, 2010).

Occupation-specific: Certain occupational groups are at increased risk of TB. Exposure of miners to silica dust has been associated with increased risk of developing TB (NIOSH, 2002; Rees & Murray, 2007; Gottesfeld et al, 2011; Stuckler et al, 2013). The frequently high HIV-burden in miners places them at additional TB risk (Fielding et al, 2011). Health care workers treating TB patients are also at increased risk of infection, and the fraction of TB in the population due to this occupational exposure has been estimated at about 0.4% (Baussano et al, 2011). Health care workers in low- and middle-income countries have five times greater risk of TB than the general population of these countries (Trajman & Menzies, 2010). Additionally, second-hand tobacco smoke exposure in the workplace, a risk factor for TB infection, is still common in certain regions, frequently being the most common occupational carcinogen (Jaakkola & Jaakkola, 2006). As the epidemiological impact of focusing on diagnosis and treatment alone has been less than expected, for example due to challenges posed by multidrug resistance and weak health systems, interventions sustainably addressing living and working conditions, as well as specific risk factors are required to meet long-term targets (Lönnroth et al, 2009).

Examples of interventions

Occupations at increased risk include health care workers (WHO, 2009c; 2014b).

- Engineering controls, such as ventilation systems and UVGI.
- TB surveillance among health care workers.
- Administrative controls, such as triage and separation of infectious patients, and worker and patient education and training in PPE.

Examples of occupational or environmental interventions of the epidemiological literature

- Strong national policies in the United States of America, including establishment of a research entity to provide scientific evidence and a regulatory agency to mandate and monitor compliance, systematic inspections for compliance and penalties for non-compliance, reduced TB in health care workers considerably (Chai et al, 2013).
- Engineering controls, such as ventilation and disinfection, e.g. with UVGI; administrative controls, such as institutional policies to reduce time between the arrival of patients at health care facilities and their diagnosis, treatment and placement in respiratory isolation, and personal protection, such as wearing respiratory masks, and treatment of latent and active TB are effective interventions in the health care setting for nosocomial TB prevention (Trajman & Menzies, 2010).
- Workplace interventions for HIV and TB diagnosis and treatment of health care workers consistently showed positive outcomes, such as increased uptake and adherence to treatment, better clinical outcomes and less risky behaviour (Yassi et al, 2013).

Other infectious and parasitic diseases

Several infectious and parasitic diseases are not considered separately in terms of health statistics, but may still have an occupational component. Examples include leptospirosis – through occupational exposure to infected animal urine or water containing animal urine; Q fever through occupational contact while processing infected animals; rabies, through contact with domestic animals; Brucella infections through contact with infected animals (Heymann, 2008) and Ebola virus disease of health care workers and laboratory personnel in epidemic areas (Katz & Tobian, 2014).



Occupational contact with animals and their excreta is a risk factor for many diseases, such as leptospirosis, rabies and brucellosis.

NONCOMMUNICABLE DISEASES

Cancers

- **Trachea, bronchus and lung cancer: 25% attributable to occupational risks (CRA)**
- **Mesothelioma: 63% attributable to occupational risks (CRA)**
- **Leukaemia: 2.1% attributable to occupational risks (CRA)**
- **Larynx cancer: 8.6% attributable to occupational risks (CRA)**
- **Nasopharynx cancer: 1.7% attributable to occupational risks (CRA)**
- **Kidney cancer: 0.1% attributable to occupational risks (CRA)**
- **Ovarian cancer: 0.5% attributable to occupational risks (CRA)**
- **Other cancers: no GBD estimate**

Overview: Cancers are characterized by abnormal cell development beyond their normal boundaries and infiltration in surrounding or remote tissue, in any part of the body (WHO, 2017c). Cancer is the second leading cause of death globally and was responsible for 8.8 million deaths in 2015.

Occupation-specific: Overall, cancer deaths from occupational exposures cause 0.8% of global mortality. Approximately 2–8% of all cancers are estimated to be caused by occupational exposures to carcinogens (Purdue et al, 2015). In the United Kingdom, for example, 5.3% of all cancer deaths were estimated to be caused by occupational risks (Rushton et al, 2012). Occupational cancers were also shown to be a substantial economic burden in different European countries (García Gómez et al, 2012; Binazzi et al, 2013; Serrier et al, 2014).

Lung cancer caused 1.7 million deaths in 2015 and is the largest contributor to cancer-related mortality (WHO, 2017c). Smoking is the most important risk factor for developing lung cancer, however, many different occupational agents are proven (i.e. supported by sufficient evidence) lung carcinogens in humans (IARC, 2017). One example is exposure to the natural radioactive gas radon. Lung cancer can occur, for example, in miners. This occupation is associated with increased lung cancer risk, with evidence of a dose-response relationship (increased lung cancer risk with increased levels of radon exposure) (Sheen et al, 2016). Another example is occupational asbestos exposure (including chrysotile), which leads to lung cancer and mesothelioma, a rare cancer predominantly of the outer lining of the lung (Nielsen et al, 2014; IARC, 2017). Workers are frequently exposed to second-hand tobacco smoke, a known risk factor for lung cancer (Jaakkola & Jaakkola, 2006). It was estimated that 25% (21–28%) of trachea, bronchus and lung cancer and 63% (49–77%) of mesothelioma burden in 2015 were attributable to occupational carcinogens (in DALYs) (IHME, 2016).

Examples of interventions

Occupations at increased risk include workers exposed to industrial or agricultural carcinogens or to radiation (WHO, 2007a).

- Regulations/standards to reduce carcinogenic substance in the workplace.
- Engineering controls, such as capsulation and closed processes in which occupational carcinogens are not released into the working environment.
- Monitoring of workers' exposure through, for example, personal film badge dosimeters which are usually worn around the worker's chest to assess the cumulative radiation dose.
- Administrative controls, such as policies for smoke-free workplaces, access to healthy food and promotion of physical activity in workplaces, worker education and training.
- PPE.

Colon and rectum cancers caused nearly 800 000 cancer deaths in 2015 (WHO, 2017c). These cancers were shown to be related to low physical activity (Lee et al, 2012; Wang et al, 2012; Park et al, 2014; IHME, 2016) which is fostered by sedentary working conditions. The International Agency for Research on Cancer (IARC) lists radiation (supported by sufficient evidence) and asbestos (supported by limited evidence) as two further potential occupational risk factors for this type of cancer (IARC, 2017).

Breast cancer is the most deadly cancer in women with nearly 600 000 deaths in 2015 (WHO, 2017c). Physical inactivity or low physical activity e.g. due to sedentary occupations is associated with breast cancer (Lee et al, 2012; Wang et al, 2012; IHME, 2016). The causal link with ionizing radiation, as it can occur in the workplace, is supported by strong evidence from studies of women exposed at younger ages (IARC, 2017). Causal links to several other potential occupational exposures, such as polychlorinated biphenyls (PCBs), ethylene oxide and shift work that involves circadian disruption, are supported by limited evidence (IARC, 2017).

Both **lymphomas/multiple myelomas** and **leukaemia** were responsible for around 300 000 deaths in 2015 (WHO, 2017k). Causal links have been reported for numerous occupational exposures, e.g. exposures to benzene, formaldehyde, chemicals in rubber manufacturing processes and ionizing radiation (sufficient evidence), and various pesticides and herbicides (diazinon, glyphosate, malathion), chemicals (solvents such as dichloromethane, trichloroethylene), and occupational exposures in petroleum refining (limited evidence) (IARC, 2017). High benzene exposure, occurring, for example, in the production of many organic chemicals and some types of rubber, dyes, pesticides or detergents, has been associated with a nearly tripled leukaemia risk (Khalade et al, 2010). Formaldehyde, a substance widely used in manufacturing, is a common airborne exposure at work. Exposure to formaldehyde as a cause of leukaemia is supported by sufficient evidence (IARC, 2017). Also X- and gamma-radiation cause leukaemia (supported by sufficient evidence) (IARC, 2017). It is estimated that 2.1% (1.0–3.6%) of global leukaemia is attributable to occupational risks (IHME, 2016).

Mouth and oropharynx cancer were responsible for over 300 000 deaths in 2015 (WHO, 2017k). The causal link between exposure to asbestos, as it occurs, for example, through inhalation of asbestos fibres in the working environment, and larynx cancer, is supported by sufficient evidence (IARC, 2017). Significantly increased risk of **larynx cancer** also has been observed for many production and transport professions, including miners, tailors, blacksmiths, toolmakers,



Cancer is a major cause of deaths worldwide with a considerable share being caused by occupational carcinogen exposure.



Cancer can be prevented by eliminating or substituting carcinogenic substances in the workplace.

painters, bricklayers, carpenters and transport equipment operators, and potential risks include exposure to polycyclic aromatic hydrocarbons, engine exhaust, textile dust and working in the rubber industry (pooled risks from meta-analyses) (Paget-Bailly et al, 2012; Bayer et al, 2016). Wood dust and formaldehyde have been identified as risk factors for **nasopharynx carcinoma** (Jia & Qin, 2012; IARC, 2017). It is estimated that 8.6% (3.8–15.3%) of larynx cancer and 1.7% (0.06–4.2%) of nasopharynx cancer is attributable to occupational carcinogens (IHME, 2016).

More than 180 000 people died of **bladder cancer** in 2015 (WHO, 2017k). Active smoking causes a large part of those cancers, e.g. 50% of urothelial bladder cancer, but also occupational exposures, such as to aromatic amines and polycyclic aromatic hydrocarbons, play an important role (Burger et al, 2013; IARC, 2017). In painters (supported by sufficient evidence) (IARC, 2017), the relative risk for bladder cancer was increased by 25% (Guha et al, 2010). Other occupations, such as dry cleaners, hairdressers and textile manufacturers, as well as exposure to printing processes, were also linked to bladder cancer (supported by limited evidence) (IARC, 2017). The risk for hairdressers increased with longer duration in the workplace (Harling et al, 2010). Exposure to aromatic amines (e.g. 2-naphthylamine, 4-aminobiphenyl and benzidine) (IARC, 2017) (sufficient evidence) can occur through working in the plastic, chemical, dye and rubber industry (Letašiová et al, 2012). Aromatic amines are also present in diesel exhaust. More occupational risk factors, such as exposure to ionizing radiation, have been reported as being causal (sufficient evidence) (IARC, 2017).

Melanoma and other skin cancers accounted for more than 100 000 deaths in 2015 (WHO, 2017k). Ultraviolet (UV) exposure increases melanoma risk (sufficient evidence) (IARC, 2017). Occupational UV-exposure, e.g. through working outdoors, has been shown to increase the risk for basal and squamous cell carcinoma (Bauer et al, 2011; Schmitt et al, 2011). In the United Kingdom, 86% of melanomas were attributable to excess UV exposure (Parkin et al, 2011). Other potential occupational exposures, such as PCBs, arsenic, soot and ionizing radiation, have also been linked to cancer of the skin (sufficient evidence) (IARC, 2017).

Various other cancer types are associated with occupational exposures, for example, **cervical, ovarian, prostate, liver, stomach, thyroid and kidney cancer**. Plutonium and vinyl chloride are associated with an increased risk of liver cancer (sufficient evidence) (IARC, 2017). Asbestos exposure is a risk factor for cancer of the ovaries and the mesothelium (sufficient evidence) (Camargo et al, 2011; IARC, 2017).

Trichloroethylene, an industrial solvent, is a risk factor for kidney cancer (sufficient evidence) (IARC, 2017). About 0.5% (0.2–1.0%) of ovarian cancer and about 0.1% (0.03–0.2%) of kidney cancer was estimated to be attributable to occupational risks in 2015 (IHME, 2016). Various occupational factors have been suggested as risks for prostate cancer, including exposures in the rubber industry, and to arsenic, cadmium and the insecticide malathion (limited evidence) (IARC, 2017). Working in rubber manufacturing (sufficient evidence) (IARC, 2017) is an established risk factor for stomach cancer. There is furthermore evidence for an association between asbestos exposure and stomach cancer (limited evidence) (Peng et al, 2014; IARC, 2017). Increased risks are also caused by ionizing radiation for bone, oesophagus, stomach, colon and rectum, brain, thyroid and salivary gland cancers (IARC, 2017).

Examples of occupational or environmental interventions from the epidemiological literature

- Legislation on cancer-related chemicals, e.g. the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulations of the European Union, can have a major influence on controls on the production, import and use of industrial chemicals (Rigolle et al, 2013). Further examples of existing national and international environmental health policies for cancer prevention can be found in Espina et al (2013).
- Regulations for substitution and phasing out of replaceable processes or carcinogenic substances in the workplace, by replacing them with less dangerous substances (Espina et al, 2015).
- Occupational carcinogen exposure (CAREX) databases have been established in different European countries and in Canada (CAREX Canada, undated; Finnish Institute of Occupational Health, undated). These exposure databases estimate numbers of workers exposed to different carcinogens by industry and, if possible, by further variables, and they assist to identify high-risk groups, set priorities for prevention, monitor trends and assess the impact of changing regulations (Peters et al, 2014).

Lung cancer

- Banning the use of asbestos decreased the risk of malignant pleural mesothelioma (Järholm & Burdorf, 2015).
- Smoke-free workplace legislation reduced exposure to second-hand tobacco smoke and thereby the risk for lung cancer in various countries (Jaakkola & Jaakkola, 2006).
- Workplace interventions for smoking cessation, such as group therapy programmes, individual counselling, pharmacotherapies, and multiple intervention programmes aimed mainly or solely at smoking cessation, effectively reduced smoking rates (Cahill & Lancaster, 2014).

Melanoma and other skin cancer

- Educational and multi-component interventions can increase sun protective behaviour among outdoor workers (Azizi et al, 2000; Buller et al, 2005; Stock et al, 2009; Reinau et al, 2013; Horsham et al, 2014).

Cervical cancer

- Worksite interventions can increase cervical cancer screening among female workers (Allen et al, 2001; Abdullah et al, 2013).

Mental, behavioural and neurological disorders

- **Depression: 10.9% attributable to occupational risks (expert opinion)**
- **Drug and alcohol use: 15.8% attributable to occupational risks (expert opinion)**

Overview: Mental, behavioural and neurological disorders account for only 4.1% of deaths worldwide, but nearly 10% of the global disease burden (WHO, 2017k). Approximately, 15% of adults aged 60 and older suffer from a mental or neurological disorder (WHO, 2017r). Main mental disorders include unipolar depressive disorder, bipolar disorder, schizophrenia, alcohol and drug use disorders, anxiety disorder, eating disorder, development disorders and intellectual disability. Main neurological disorders include Alzheimer's disease and other dementias, Parkinson's disease, epilepsy, multiple sclerosis, and migraine and non-migraine headache. Depressive disorder is the largest among these conditions, and affects more than 300 million individuals worldwide (WHO, 2017h).

Occupation-specific: Most of the above listed disorders have a small to moderate link to occupation. It has been postulated that workplace mental health interventions simultaneously: a) reduce work-related risk factors for both clinical (e.g. depression, anxiety disorders) and sub-clinical (e.g. psychological distress) mental health problems; b) develop positive work aspects, worker strength and capacities; and c) address mental health problems among workers regardless of cause (LaMontagne et al, 2014).

Depression has been linked to occupational stress, for example through high demands and low control in the workplace (Tennant, 2001; Wang et al, 2008; Andrea et al, 2009; Niedhammer et al, 2014; Madsen et al, 2017) and certain occupations, e.g. nurses and workers in certain industries (Battams et al, 2014; Silva et al, 2015). Job strain, low decision latitude, low social support and high psychosocial demands at work, and job insecurity were significantly associated with common mental disorders, including mainly mild-to-moderate depressive and anxiety disorders (Stansfeld & Candy, 2006). Work-life imbalance was further reported to contribute to depression (Hämmig & Bauer, 2009). Depression has also been linked to the use of certain pesticides in agriculture, although evidence is limited (Freire & Koifman, 2013) and to frequent international business travel (Patel, 2011). Drug and alcohol use have been linked to the occupational environment, such as coca growing, or working in the entertainment or alcohol industry (Tutenges et al, 2013). It has been estimated that 11% (4–31%) of depression and 16% (6–38%) of drug and alcohol use can be attributed to occupational risks (Prüss-Ustün et al, 2016).

Examples of interventions

- Health and safety policies and practices for identifying distress, harmful use of psychoactive substances and illness and for providing resources and support to manage them, involvement of employees in decision-making, organizational practices supporting a healthy work-life balance, programmes for employee career development, and recognition of employee contribution (WHO, 2017q).
- The risk management paradigm (Kallman & Maric, 2004) has been recommended to effectively manage psychosocial risks and has been judged as more effective than simple workplace interventions or other tools (van Stolk et al, 2012).



Occupational risks, such as work stress and high demands, are thought to be a cause of depression and alcohol use.

Professional groups at increased risk of exposure to **post-traumatic stress disorders** include mainly police officers, firefighters, ambulance and military personnel and humanitarian relief workers, due to frequent exposure to traumatic events (Wells et al, 2011; Connorton et al, 2012; Skogstad et al, 2013). **Mood and anxiety disorders** were also linked to work stress and imbalance between work and family/personal lives (Wang, 2006; Wang et al, 2008; Andrea et al, 2009).

Occupational lead exposure has been associated with cognitive decline in workers (Schwartz et al, 2005). Occupational exposures to various chemicals such as lead, methylmercury and endocrine disrupting chemicals to women of childbearing age might lead to neurodevelopmental effects in children, such as attention deficit disorders, intellectual disability and autism (Axelrad et al, 2007; De Cock et al, 2012; Bergman et al, 2013; Polanska et al, 2013; Grandjean & Landrigan, 2014; Polanska et al, 2014).

Parkinson's disease has been associated with occupational exposure to pesticides (Allen & Levy, 2013). Links between Parkinson's disease and other neurodegenerative diseases, such as Alzheimer's disease, and a variety of pesticides, solvents and metals that can occur in the workplace have been suspected, but the evidence is not yet conclusive (Jiang et al, 2013; Baltazar et al, 2014; Tanner et al, 2014). **Epilepsy** has been linked to head injury (WHO, 2018a), that can occur in the workplace. Also, exposure to methylmercury, as it occurs in industrial processes, has been linked to epilepsy (Yuan, 2012). Furthermore, epilepsy has been put forward as a consequence of certain other diseases, which themselves are associated with occupation, such as stroke. Links between second-hand tobacco smoke exposure, organic solvents and shift work, and multiple sclerosis have been suggested (Hedström et al, 2015).

Insomnia has occupational components, mainly through occupational stress, irregular working hours, shift work or jet lag (Porkka-Heiskanen et al, 2013). Triggers for **migraine** and other headaches were reported to include bright lights, air quality, odours, stress and noise. Remediation of triggers in the workplace may improve attendance and productivity (Friedman & De Ver Dye, 2009).

In Finland it has been estimated that 4% of mental disorders and 3% of nervous system diseases are linked to occupation (Nurminen & Karjalainen, 2001). In France, 15–20% of mental disorders are attributable to job strain for men, and 14–27% for women (Sultan-Taïeb et al, 2013). In Europe, 18% and 4.5% of mental disorders are attributed to job strain and job insecurity, respectively (Niedhammer et al, 2013).



Irregular working hours and shift work have been linked to insomnia, cancer, ischaemic heart disease and multiple sclerosis.

Examples of occupational or environmental interventions from the epidemiological literature

- Organizational interventions (work changes) might lead to improvements in teacher well-being and retention rates (low quality evidence) (Naghieh et al, 2015). There is also low quality evidence that cognitive behavioural training, mental and physical relaxation and changed work schedules reduce stress in health care workers (Ruotsalainen et al, 2015).
- Workplace bullying, a reason for psycho-social stress at work, might be prevented through organizational and individual interventions (very low quality evidence) (Gillen et al, 2017). Furthermore, interventions are available to provide bullying targets with assertiveness skills, counselling support and redress (Kemp, 2014).
- Psychosocial interventions might reduce psychological symptoms in police officers (Peñalba et al, 2008).
- A systematic review of economic evaluations concluded that worksite interventions to prevent or treat mental health problems might be cost effective (Hamberg-van Reenen et al, 2012).
- There are many more interventions at the workplace, e.g. mindfulness training and other stress management or stress reduction programmes (many web- or computer-based), that had positive psychological effects in workers. The listed interventions are just a selection, focusing on reviews of the available literature.

Depression and anxiety

- Work-directed interventions, such as modifying work tasks, reducing (temporarily) working hours, and individual work support, delivered in combination with a clinical intervention to depressed people, reduced sickness absence compared with clinical intervention alone (Nieuwenhuijsen et al, 2014).
- A work-focused cognitive behavioural therapy, in combination with individual work support, increased or maintained work participation in people with common mental disorders compared with usual care and, additionally, reduced depression and anxiety symptoms and increased health-related quality of life (Reme et al, 2015). These findings are supported by a previously conducted systematic review (Pomaki et al, 2012).
- Mental health interventions, such as interventions based on cognitive behavioural therapy, mental health literacy, exercise and team-based participatory intervention, applied to all workers irrespective of risks or disease might reduce overall depressive symptoms in a workforce (Tan et al, 2014).
- Physical activity and yoga interventions at the workplace were shown to reduce depressive symptoms and anxiety. Limited evidence for stress relief was also observed (Chu et al, 2014).
- Different interventions in night shift workers, such as fast-forward rotating shifts, controlled light exposures, physical activity, healthy diet and health promotion were shown to improve sleep and reduce adverse chronic disease outcomes (Neil-Sztramko et al, 2014).

Cataracts

No GBD estimate

Overview: Unoperated cataracts are the leading cause of blindness worldwide (WHO, 2017ab). Globally, unoperated cataracts are responsible for 25% of moderate to severe vision impairment and 35% of blindness. A cataract is the clouding of the lens of the eye, which prevents clear vision. Cataracts can be removed surgically, but access to the required medical services is limited in many countries (WHO, 2017ab). The prevalence of cataracts increases with age.

Occupation-specific: Ultraviolet light exposure, which is increased in outdoor workers but also frequently in other workers such as welders (ICNIRP, 2007), is a significant factor in the genesis of cataract. Globally, about one fifth of cortical cataracts have been attributed to UV radiation (Lucas et al, 2008). The depletion of the stratospheric ozone layer has led to increasing UV exposure, and, accordingly, the risk of cataract development is likely to further increase (Norval et al, 2011). Occupational groups exposed to ionizing radiation, such as medical personnel or nuclear accident clean-up workers, are also at increased risk of cataract development (Hammer et al, 2013).



About one fifth of cataracts are caused by ultraviolet exposure.

Examples of interventions

Occupations at increased risk include outdoor workers and welders with UV light exposure (ICNIRP, 2007).

- Engineering controls, e.g. to shield the welding workplace.
- Administrative controls, such as reducing working time in the midday sun and worker education and training, e.g. for wearing eye protection and protective behaviour.
- PPE.

Examples of occupational or environmental interventions from the epidemiological literature

- Educational and multi-component interventions can increase sun protective behaviour among outdoor workers (Azizi et al, 2000; Buller et al, 2005; Stock et al, 2009; Reinau et al, 2013).

Hearing loss

25% attributable to occupational noise (CRA)

Overview: Approximately 360 million individuals suffer from disabling hearing loss worldwide, the majority being adults (WHO, 2017f). Disabling hearing loss refers to a hearing loss greater than 40dB in the better ear in adults – 25dB or better in both ears being the hearing threshold for normal hearing (WHO, 2017f). It is estimated that over one third of the global population ≥ 65 years of age are affected by hearing loss, most notably in regions of South Asia, Asia Pacific and sub-Saharan Africa (WHO, 2017f).

Occupation-specific: Workers may be exposed to excessive noise and ototoxic substances which increases their risk of hearing loss (Kurmis & Apps, 2007; EU-OSHA, 2009; Nies, 2012). It was estimated that in the United States of America alone 30 million workers were exposed to potentially damaging levels of noise (Stucken & Hong, 2014). Work in certain sectors, such as mining, manufacturing, construction or night clubs, is associated with an increased risk of occupationally acquired hearing loss (Kurmis & Apps, 2007). Globally, exposure to excessive noise at work caused 25% (22–29%) of hearing loss in 2015 (IHME, 2016).

Examples of occupational or environmental interventions from the epidemiological literature

- Implementation of stricter legislation can reduce noise levels in workplaces (very low quality evidence). Evidence from case studies exists for engineering controls on noise levels; however, effectiveness has not been assessed in controlled studies. Hearing protection devices might be effective in preventing hearing loss but this depends on training and correct use. (Tikka et al, 2017). Training in appropriate use of earplugs can significantly affect their efficacy (Salmani Nodoushan et al, 2014).
- An analysis examining occupational noise legislation in Latin America, Canada and the United States of America found considerable differences in the protection of workers against occupational noise between countries, with 27% of countries having no established regulations on occupational noise leaving millions of workers unprotected (Arenas & Suter, 2014).
- The Queensland Symphony Orchestra in Australia developed and implemented a hearing conservation strategy consisting of noise exposure monitoring, earplugs specifically designed for musicians, a noise committee and hearing evaluation programme, engineering controls, such as use of risers and acoustic screens, administrative controls, such as rostering and seat rotation, and an education package directed at musicians (O'Brien et al, 2015).

Examples of interventions

Occupations at increased risk include miners, and manufacturing and construction workers.

- Engineering controls, such as reducing noise emission from industrial machinery.
- Administrative controls, such as limiting the time a worker spends in noisy environments.
- PPE, such as earmuffs and plugs.
- Comprehensive programmes also include noise monitoring and awareness raising/training among workers, as well as audiometric testing (OSHA, no date; Hong et al, 2013). Similarly, monitoring and control measures can reduce exposure to ototoxic substances (EU-OSHA, 2009).



Exposure to excessive noise at work is estimated to be responsible for 25% of hearing loss.

Ischaemic heart disease

No GBD estimate

Overview: Cardiovascular diseases, including ischaemic heart disease (IHD) and stroke, are the leading cause of mortality worldwide (WHO, 2017d). In 2015, 17.7 million people died from cardiovascular diseases; of those an estimated 7.4 million were due to IHD. High blood pressure, unhealthy diet, physical inactivity and tobacco smoke are the most important risk factors, but also different environmental factors, such as lead or air pollution, are crucial causes of the disease (Forouzanfar et al, 2016; WHO, 2017d).

Occupation-specific: Working conditions have been associated with IHD, including stress, for example, through high demand and lack of social support (Pejtersen et al, 2014), working more than 55 hours per week (Kivimäki et al, 2015), as well as occupational exposures to air pollution (Fang et al, 2010) and noise (Skogstad et al, 2016). Psychosocial stress at work (high demand and low control) was found to increase the risk for IHD by 23%, and 3.4% of all IHD cases were attributed to this risk factor (Kivimäki et al, 2012). High versus low job insecurity was also associated with a 32% higher likelihood of IHD (Virtanen et al, 2013). Shift work increased coronary events by 24% and myocardial infarctions by 23% (Vyas et al, 2012). Sedentary behaviour, with sedentary work as a main component, was estimated to increase the risk of cardiovascular disease by 18% (Chomistek et al, 2013).

Another occupational risk factor for IHD is exposure to lead. Occupational lead exposures, e.g. working in the mining and processing industries (Poręba et al, 2011), can increase blood pressure (Navas-Acien et al, 2007), which is the most important risk factor for IHD. Furthermore, evidence has emerged linking persistent organic pollutants to the disease (Lind & Lind, 2012). Certain groups of workers are also exposed to higher air pollution levels from traffic than the general population, and may disproportionately be affected from the large burden of disease caused by air pollution. These may include, for example, the traffic police or highway workers (Choudhary & Tarlo, 2014).

Several estimates of health impacts from occupation on cardiovascular diseases have been made in the past. Some 10–20% of all causes of cardiovascular disease deaths among the working age population were estimated to be work-related (Tsutsumi, 2015). In total, occupational risks accounted for 17% of deaths from IHD in Finland (Nurminen & Karjalainen, 2001). In the United States of America, about 12% of the IHD burden was related to occupation, for the age group 20–69



Sedentary behaviour, and stress through high demands at work, are risk factors for cardiovascular disease, the leading cause of mortality worldwide.

years (Steenland et al, 2003). The proportion of IHD cases attributable to workplace second-hand tobacco smoke exposure was estimated to range, by country, between 1–9% (Jaakkola & Jaakkola, 2006). In France, between 8.8–10.2% of IHD morbidity, and between 9.4% and 11.2% of IHD mortality, respectively, were estimated to be attributable to job strain in men (Sultan-Taïeb et al, 2013). In France, the costs of IHD incurred by job strain, including medical and sick leave costs, amounted to €101 million in 2003 (Sultan-Taïeb et al, 2013). In the United States of America, indirect costs – due to lost productivity – from cardiovascular disease are estimated to increase from US\$ 172 billion in 2010 to US\$ 276 billion in 2030 (Heidenreich et al, 2011).

Stroke

No GBD estimate

Overview: Stroke is the second most important cause of global mortality, causing 6.7 million deaths in 2015 (WHO, 2017d). Risk factors for stroke are similar to those for IHD, and include high blood pressure, unhealthy diet, physical inactivity, tobacco smoke and harmful use of alcohol.

Occupation-specific: Occupational risks also play an important role in stroke burden; shift work and workplace exposure to second-hand tobacco smoke significantly increase stroke (Jaakkola & Jaakkola, 2006; Vyas et al, 2012), as well as long working hours (more than 55 hours per week) (Kivimäki et al, 2015). The proportion of stroke cases attributable to workplace second-hand tobacco smoke exposure was estimated to range, by country, between 1–24% (Jaakkola & Jaakkola, 2006). In Finland, it was estimated that occupational risks accounted for 11% of deaths from stroke (Nurminen & Karjalainen, 2001). Additionally, job strain resulting from high workload and few decision-making opportunities at the workplace is associated with hypertension (Rosenthal & Alter, 2012; Babu et al, 2014) and some professions are especially prone to elevated blood pressure levels (Kales et al, 2009).

Occupational exposure to lead results in high blood pressure (Navas-Acien et al, 2007; Poręba et al, 2011), which is the most important risk factor for cerebrovascular disease. Also, sedentary working conditions might increase stroke risk, as physical activity has been shown to protect against stroke (Wendel-Vos et al, 2004; Hu et al, 2005).



Air pollution from a copper-nickel plant.

Examples of interventions (cardiovascular diseases)

Occupations at increased risk include industrial and construction workers in settings where lead is being used (NIOSH, 2013).

- Replacement of lead-containing products with safer alternatives whenever possible.
- Engineering controls, such as ventilation.
- Blood lead monitoring of exposed workers.
- Worker education and training on hazards and safe work practices, PPE.

Occupations at increased risk also include emergency responders such as police and firefighters and workers exposed to shift work and high job strain.

There are also public health interventions not specific to the working population (WHO, 2017d):

- Comprehensive tobacco control policies.
- Promotion of foods low in fat, sugar and salt.
- Promotion of physical activity.
- Strategies to reduce harmful use of alcohol.

In the light of the available evidence on the linkages between the workplace and cardiovascular disease, national surveillance to identify elevated levels of hazardous work characteristics; regulations to limit occupational psychosocial stressors, establishment of upper limits of work hours and mandatory vacation time; and legislation for increased economic security of workers has been called for (Schnall et al, 2016).

Examples of occupational or environmental interventions from the epidemiological literature

- Workplace screening for hypertension, diabetes and obesity as risk factors for cardiovascular disease can be effective in identifying undiagnosed risks and ensuring subsequent treatment in employees (Gray et al, 2014; Legorreta et al, 2015).
- Workplace health promotion and programmes were shown to have beneficial effects on blood pressure (Eng et al, 2016), biomarkers of diabetes (Lévesque et al, 2015) or cardiovascular disease (Korshøj et al, 2015; Kramer et al, 2015; Lim et al, 2015), workers' weight and fruit and vegetable intake (Afshin et al, 2015) and smoking cessation (Cahill & Lancaster, 2014). A systematic review on lifestyle-focused interventions at the workplace to reduce the risk for cardiovascular disease found strong evidence for a positive effect on body fat but not for other assessed outcomes (blood pressure, blood lipids, blood glucose) (Groeneveld et al, 2010). The American Heart Association/American Stroke Association promotes and supports comprehensive workplace wellness programmes (Fonarow et al, 2015).
- In the United States of America, a large company introduced a worksite health promotion programme in 1979. This was evaluated from 2002–2008 and effectively reduced obesity, high blood pressure, high cholesterol, tobacco use, physical inactivity and poor nutrition and saved between US\$ 1.88–3.92 in medical spending for every US\$ 1 invested in the programme (Henke et al, 2011). This finding is consistent with a systematic review and meta-analysis which found a US\$ 3.27 reduction in medical and US\$ 2.73 in absenteeism costs for every US\$ 1 spent in workplace health promotion programmes (Baicker et al, 2010).

Smoking

- The introduction of legislative smoking bans leads to improved health outcomes through the reduction of second-hand tobacco smoke exposure with the clearest evidence observed for reduced admissions for acute coronary syndrome (Frazer et al, 2016). Banning second-hand tobacco smoke in the workplace led to improvements in cardiac health (Jaakkola & Jaakkola, 2006).
- A study estimated that introducing smoke-free legislation in all workplaces in the United States of America would result in nearly US\$ 49 million savings in direct medical costs. Reductions in second-hand tobacco smoke accounted for the majority of these savings (Ong & Glantz, 2004).
- Implementing smoke-free workplaces was about nine times more cost effective per new non-smoker than free nicotine replacement therapy programmes (Ong & Glantz, 2005).
- Workplace interventions for smoking cessation, such as group therapy programmes, individual counselling, pharmacotherapies, and multiple intervention programmes aimed mainly or solely at smoking cessation, effectively reduced smoking rates (Cahill & Lancaster, 2014).

Chronic obstructive pulmonary disease

12% attributable to occupational risks (CRA)

Overview: Chronic obstructive pulmonary disease (COPD), a slowly progressing disease characterized by a gradual loss of lung function, caused 2.7% of overall global disease burden (in terms of DALYS) in 2015 (WHO, 2017k). The most important risk factor is active smoking, estimated to contribute to 40% of the global COPD burden in 2016 (IHME, 2018). However, around one third of patients with COPD never smoked (Salvi & Barnes, 2009). Most other risk factors are environmental or occupational, including dusts and chemicals in the workplace, air pollution and second-hand tobacco smoke.

Occupation-specific: A substantial part of the COPD disease burden is attributable to occupation, e.g. from particulate matter, gases and fumes. It has been estimated that 12% (6–19%) of the overall COPD disease burden (DALYs) in 2015 (IHME, 2016) and up to 40% (Blanc, 2012) of COPD cases in those who have never smoked might be attributable to the workplace.

Occupations with high risk for COPD include: coal and hard-rock mining (Cohen et al, 2008; Santo Tomas, 2011), metal smelting (Søyseth et al, 2013), tunnel and construction work and manufacture of concrete, plastic, textile (Lai & Christiani, 2013), rubber, leather and food products, transportation and trucking (Hart et al, 2012), automotive repair, some personal services (e.g. beauty care), and farming (Salvi & Barnes, 2009; Poole, 2012). Additionally, second-hand tobacco smoke exposure in the workplace is a considerable risk to health (Eisner, 2010) and it was estimated that workplace exposure in the United States of America increases the chance for COPD up to 36% (Eisner et al, 2005).

Examples of interventions

Occupations at increased risk include agricultural workers, construction workers, miners, welders, and workers in the rubber or plastics industry (HSE, undated; Fransman et al, 2008; CDC, 2011).

- Engineering controls, such as physical containment or segregation of the emission source, application of general, local exhaust and specialized ventilation and dust suppression techniques.
- Policies for smoke-free workplaces.



A substantial proportion of COPD cases is caused by occupational smoke exposure.

Examples of occupational or environmental interventions of the epidemiological literature

- Based on 90 studies that compared exposure with and without control measures in workplaces, the average percentage reduction of exposure to risks causing occupational disease, such as COPD, work-related cancer, pneumoconiosis and asthma, and injury was 50% (4–74%) for enclosures of sources of pollution; 82% (78–84%) for local exhaust ventilation; 87% (73–94%) for specialized ventilation systems; 43% (17–61%) for general ventilation; 83% (77–88%) for dust suppression techniques; and 87% (71–95%) for separation of workers. These exposure reductions can reduce work-related cancer, pneumoconiosis, COPD, asthma and various other respiratory diseases (Fransman et al, 2008; Verbeek & Ivanov, 2013).

Smoking

- Exposure to second-hand tobacco smoke as well as respiratory and sensory irritation symptoms were significantly reduced in bar and restaurant workers after the introduction of smoke-free legislation in Scotland and Argentina (Menzies et al, 2006; Schoj et al, 2010). Smoking cessation interventions delivered at the workplace or elsewhere that are directed at individual smokers, such as individual and group counselling, pharmacological treatment and multiple interventions targeting smoking cessation as the primary or only outcome, increase the likelihood of quitting smoking (Cahill & Lancaster, 2014).

Asthma

9.7% attributable to occupational risks (CRA)

Overview: Asthma, an inflammatory respiratory condition, is a major cause of disability, health care utilization and reduced quality of life. An estimated 235 million people suffer from asthma and there were nearly 400 000 deaths due to asthma in 2015 (WHO, 2017a). In children, asthma is one of the most important chronic diseases, with a mean of 14% of children around the world reporting asthma symptoms (Pearce et al, 2007).

Genetic predisposition is one major asthma determinant (Moffatt et al, 2010). However, large geographic differences and important recent time trends in asthma occurrence are likely to be in part due to variations in environmental factors (Eder et al, 2006; Heinrich, 2011; Tinuoye et al, 2013). The pathogenesis of asthma can start as early as in utero and both asthma development and exacerbation can be triggered by different indoor and outdoor environmental exposures.

Occupation-specific: Work-related asthma is among the most frequent occupational diseases (Baur, Aasen et al, 2012). It was estimated that around 18% of all adult-onset asthma is caused by occupational factors (Torén & Blanc, 2009) and that around 22% of adults with asthma suffer from work-exacerbated asthma (Henneberger et al, 2011). Many agents in the workplace are supposed to be responsible for the development of the disease (Baur, Bakehe et al, 2012). Those can be grouped as allergens and irritants and include, amongst many others, cleaning agents, disinfectants, isocyanides, enzymes, coffee, flour, animals and greenhouse allergens, wood dust, colophony, latex and metals (Pérez-Ríos et al, 2010; Moscato et al, 2011; Vandenplas et al, 2011; Folletti et al, 2014). Also, exposure to second-hand tobacco smoke, as it frequently occurs in the workplace (Jaakkola & Jaakkola, 2006), was shown to increase occurrence and severity of asthma (Eisner, 2008). PAFs for asthma in different European countries and the United States of America from exposure to second-hand tobacco smoke in the workplace were estimated between 1–29% (most countries between 10–20%) (Jaakkola & Jaakkola, 2006). Second-hand smoke exposure to unborn children can impact lung growth and development (Wang & Pinkerton, 2008) and lead to asthma in later life (Burke et al, 2012). Dampness and mould in offices was associated with the “sick building syndrome”; a constellation of different symptoms related to indoor environments, including irritation of the upper respiratory tract, as well as increased bronchial responsiveness and eosinophilic inflammation, usually present in people with asthma (Zhang et al, 2012). The workplace

Examples of interventions

Occupations at increased risk are workers exposed to allergens and irritants at work such as cleaning agents, disinfectants, isocyanides, enzymes, coffee, flour, animals and greenhouse allergens, wood dust, colophony, latex and metals (NIOSH, 2017).

- Elimination or substitution of processes or materials that lead to exposure of allergens and irritants.
- Engineering controls, such as enclosed processes and local exhaust ventilation.
- Administrative controls, such as policies for smoke-free workplaces, safe work practices, exposure reduction and prevention and worker education and training on hazards and healthy work practices.



Work-related asthma is among the most frequent occupational diseases.

might also offer a protective effect: exposure to a farming environment in childhood was associated with a decrease in subsequent doctor-diagnosed asthma and current wheeze by 25% (Genuneit, 2012). The total present value costs for all cases of occupational asthma in the United Kingdom in 2003 were estimated at between £95 and £135 million, with the largest economic burden born by the state and the individual (Ayres et al, 2011). The total annual costs of occupational asthma in Europe was estimated at €1.2 billion in 2008 (Jinhai, 2010).

Occupational exposures were estimated to account for about 9.7% (5.1–14.6%) of the total disease burden from asthma in 2015 (IHME, 2016).

Examples of occupational or environmental interventions of the epidemiological literature

Reducing exposure

- Reduction of exposure was associated with beneficial effect on asthma symptoms. However, the effect size was smaller and there was no improvement of lung function compared with workers that remained exposed (de Groene et al, 2011; Vandenplas et al, 2011). Eliminating exposure to asthma allergens was also effective for the primary prevention of occupational asthma (Heederik et al, 2012). However, certain causes of occupational asthma, in particular chemicals, can be more difficult to identify (Cullinan & Newman Taylor, 2010; Baur, Aasen et al, 2012).
- Repairing mould-damaged buildings and offices led to a reduction of asthma-related symptoms and respiratory infections in adults (Sauni et al, 2013).
- Replacing powdered latex gloves with low protein powder-free natural rubber latex or latex-free gloves is recommended as a strategy to prevent latex sensitization and occupational asthma, for example in health care settings (LaMontagne et al, 2006).
- Exposure to second-hand tobacco smoke as well as respiratory and sensory irritation symptoms were significantly reduced in bar and restaurant workers after the introduction of smoke-free legislation in Scotland and Argentina (Menzies et al, 2006; Schoj et al, 2010).

Engineering controls

- An intervention in South African supermarket bakeries using engineering dust controls (use of mixer lids and divider oil) with dust control training was effective in reducing flour dust and rye allergen exposure, especially when engineering controls and training were combined (Baatjies et al, 2014). In the Netherlands, an intervention targeting the flour processing industry and focusing only on risk education and providing information on good work practices modestly reduced exposure to flour dust and amylase (Meijster et al, 2009).

Increased awareness of potential hazards

- Routine surveillance of workers could become an important measure for primary and secondary prevention of occupational asthma (Szram & Cullinan, 2013). Surveillance for work-related isocyanate asthma was found to be cost-saving to society and was associated with a cost to the employer of US\$ 13 per symptom-free day (Wild et al, 2005).
- The European Academy of Allergy and Clinical Immunology recommends: a baseline health assessment before starting a vocational, school or work environmental control (as a cornerstone for prevention in the workplace); improved education for adolescents and young adults with asthma regarding potential work effects on asthma; preventive measures to limit occupational exposures; immediate reporting of all possible symptoms of work-related respiratory allergies; and medical surveillance especially in the first two to three years of exposure (Moscato et al, 2011). However, there is currently only very low quality evidence that bronchial challenge tests in pre-employment examination may have a significant effect on the incidence of occupational asthma (Schaafsma et al, 2016).

Administrative controls

- Removing people with occupational asthma from the relevant exposure was associated with beneficial effects on asthma symptoms and lung function (people removed from exposure were 21 times more likely to report an absence of asthma symptoms and experienced a mean improvement of lung function of nearly 6% (de Groene et al, 2011).
- In Germany, an educational intervention for farmers with occupational asthma reduced a marker for allergic airway inflammation (Dressel et al, 2007; 2009).
- Smoking cessation interventions delivered at the workplace or elsewhere that are directed at individual smokers such as individual and group counselling, pharmacological treatment and multiple interventions targeting smoking cessation as primary or only outcome increase the likelihood of quitting smoking (Cahill & Lancaster, 2014).

Personal protective equipment

- Dust respirators can prevent asthma attacks in patients with occupational asthma (Obase et al, 2000).

Pneumoconiosis

About 100% attributable to occupational risks (CRA)

Pneumoconiosis, including silicosis, asbestosis and coal-workers' pneumoconiosis are chronic respiratory diseases, of largely occupational origin arising through the inhalation of dusts, causing over 20 000 deaths per year (IHME, 2016). Silicosis is caused by inhalation of crystalline silica dust, a known carcinogen of the lung (IARC, 2017), and is one of the most important occupational diseases worldwide (Leung et al, 2012). Silicosis may lead to irreversible fibrosis of the lung and to progressive disability and death. Occupational exposure to crystalline silica affects millions of workers worldwide and occurs in many industries such as mining, construction and industries handling cement, iron, steel and ceramic (Leung et al, 2012). The ILO/WHO Global Programme for the Elimination of Silicosis was initiated in 1995 and supports the establishment of national silicosis control action plans (WHO, 2007b). Primary prevention control measures include substitution of materials, modification of processes and equipment, wet methods; followed by engineering measures to control silica dust emissions or transmissions such as enclosed processes, worker or source isolation and ventilation; and finally PPE and worker education and training (Leung et al, 2012).

Exposure to the carcinogen asbestos can lead to asbestosis, another form of lung fibrosis. Asbestos has been used for insulation of buildings and in a number of products such as roofing shingles, water supply lines, fire blankets and in automobiles. Although asbestos use has been banned in many countries, some 125 million workers worldwide are exposed to it. Prevention measures are similar to those for silicosis and include elimination, substitution and preventing exposures through engineering measures and personal protection when potential contact is unavoidable such as in asbestos removal (WHO, 2016a).

Coal mine dust lung diseases (CMDLD) include different entities of coal-related respiratory diseases such as silicosis, described above, coal workers' pneumoconiosis, mixed dust pneumoconiosis and dust-related diffuse fibrosis (Petsonk et al, 2013). Globally, coal mining remains an important industry with, for example, some 140 000 miners in the United States of America and more than 6 million in China (Petsonk et al, 2013). The prevalence of coal workers' pneumoconiosis was found to be around 6% in Chinese coal miners (2001–2011) (Mo et al, 2014). In the United States of America, 7% of miners with more than 25 years job exposure showed radiographic pneumoconiosis (2005–2009) (Petsonk et al, 2013). Airflow obstruction, respiratory infections, hypoxaemia, respiratory failure and cardiac problems might result from CMDLD (Petsonk et al, 2013). Prevention includes primarily setting evidence-based exposure limits for respirable coal mine dust (GAO, 2012) and, additionally, ventilation, workplace adjustments and personal protection.

Examples of interventions

Occupations at increased risk include miners and industrial and construction workers with exposure to asbestos, silica and coal dust (WHO, 2007b).

- Elimination or substitution of processes or materials that lead to silica, coal dust or asbestos exposure.
- Engineering controls, such as enclosed processes, local exhaust ventilation and dust suppression techniques.
- Administrative controls, such as work practices or policies for exposure reduction and prevention and worker education and training on hazards and healthy work practices.
- PPE.

Examples of occupational or environmental interventions of the epidemiological literature

- Based on 90 studies that compared exposure with and without control measures in workplaces, the average percentage reduction of exposure to risks causing occupational disease, such as COPD, work-related cancer, pneumoconiosis and asthma, and injury was: 50% (4–74%) for enclosures of sources of pollution; 82% (78–84%) for local exhaust ventilation; 87% (73–94%) for specialized ventilation systems; 43% (17–61%) for general ventilation; 83% (77–88%) for dust suppression techniques; and 87% (71–95%) for separation of workers. These exposure reductions can reduce work-related cancer, pneumoconiosis, COPD, asthma and various other respiratory diseases (Fransman et al, 2008; Verbeek & Ivanov, 2013).

Musculoskeletal diseases

- **Low back and neck pain: 20% attributable to occupational risks (CRA)**
- **Rheumatoid arthritis: 16% attributable to occupational risks (expert opinion)**
- **Osteoarthritis: 20% attributable to occupational risks (expert opinion)**

Overview: The main musculoskeletal diseases included in this study were rheumatoid arthritis, osteoarthritis, back and neck pain, upper limb musculoskeletal disorders and gout. These are part of a group of 150 musculoskeletal conditions affecting millions of people globally (WHO, 2003). These conditions are common, often progressive and associated with pain.

Occupation-specific: Low back pain has been associated with ergonomic stressors at work such as manual lifting and whole body vibration, and psychosocial factors are believed to contribute to morbidity (Schaafsma et al, 2015). It was estimated that occupational exposures account for 20% (15–25%) of the burden of back and neck pain in 2015 (IHME, 2016). Occupational groups at highest risk of low back pain include farmers, forestry workers and fishermen, production and related workers, and service workers (Driscoll et al, 2014). Upper limb musculoskeletal disorders, conditions involving nerves, tendons, muscles and supporting structures of the upper limb are further leading causes of disabling work-related injuries (Van Eerd et al, 2015). Several risks in the work environment have been found to be associated with higher rates of neck pain, including high job demands and low social/work support, job insecurity, poor computer workstation design and work posture, sedentary work position, repetitive and precision work, and prolonged sitting at work (Côté et al, 2008; McLean et al, 2010).

Osteoarthritis has been associated with occupational activity, for example heavy lifting, using vibrating tools, kneeling or exposure to cramped spaces (Richmond et al, 2013). Certain occupations might increase the risk for rheumatoid arthritis, such as conductors, freight and transport workers, farm workers, printmakers and process engravers. Also, exposure to silica dust, asbestos and vibrations were associated with increased rheumatoid arthritis risk (Olsson et al, 2004; Hoovestol & Mikuls, 2011). It has been estimated that 17% (6–30%) of the disease burden from rheumatoid arthritis and 20% (11–29%) of osteoarthritis can be attributed to occupational risks (Prüss-Ustün et al, 2016).

Other musculoskeletal diseases, such as other forms of arthritis, arthropaties, joint disorders, systemic connective tissue disorders, muscle and soft tissue disorders, are also often linked to occupational conditions.

Examples of interventions

Occupations at increased risk include agricultural and forestry workers, fishermen, production and service workers (EU-OSHA, 2015).

- Engineering controls, such as automation or mechanization, and ergonomic workplace design, work equipment and tools.
- Ergonomic risk assessment to identify risks that can be eliminated or need control measures.
- Administrative controls, such as adequate staffing levels, job enlargement and rotation, working hours and breaks, worker education and training on healthy work practices such as working postures and physical training to strengthen workers' physical capacity.
- PPE, such as knee protectors.
- Additionally, workers at increased risk should be identified and monitored and return-to-work strategies implemented for workers absent from work due to musculoskeletal diseases.



Manual lifting of heavy materials and poor work posture are risk factors for back and neck pain.

Examples of occupational or environmental interventions from the epidemiological literature

- An evidence-based multidisciplinary practice guideline to reduce the workload due to lifting for preventing work-related low back pain draws the following conclusions: training on lifting techniques, pre-employment medical examination and the use of back-belts are not recommended to reduce the risk of low back pain. Personal lift assist devices may be suitable to reduce the load on the back but more evidence is needed. Lifting devices can overcome the need for manual lifting but careful consideration of benefits and drawbacks must be made according to the specific situation. Changing production methods, e.g. from manual lifting to pushing and pulling, and improving the lifting situation, e.g. via devices to adjust working height for storage of materials or a rolling floor inside a truck to prevent lifting and setting down goods at ground level, can reduce the load on the low back (Kuijer et al, 2014).
- Workplace interventions, defined as changes in workplace or equipment, work design and organization, working conditions or work environment and occupational case management with active stakeholder involvement, were effective in reducing sickness absence, improving pain and functional status in workers with musculoskeletal disorders compared with usual care (van Vilsteren et al, 2015).
- Chair interventions, e.g. adjustability of the seat height and the seat pan depth, might reduce musculoskeletal symptoms in workers who are required to sit for long periods (Van Niekerk et al, 2012).
- There is some evidence for the effectiveness of job loss prevention interventions such as work changes or adaptations and vocational counselling, advice and education for workers with inflammatory arthritis (Hoving et al, 2014) and persistent musculoskeletal pain (Oakman et al, 2016).
- Workplace-based resistance training can help prevent and manage upper extremity musculoskeletal disorders (UEMSD) and symptoms (strong evidence) (Van Eerd et al, 2015). Furthermore, there is evidence that the use of arm support together with an alternative computer mouse, mouse use feedback or stretching programmes prevent UEMSD and symptoms (Hoe et al, 2012; Van Eerd et al, 2015).
- It was shown that workplace physical activity interventions can reduce musculoskeletal pain (Moreira-Silva et al, 2016). There is currently no evidence that job stress management training, ergonomic workplace adjustments or behavioural interventions are effective in the prevention or amelioration of UEMSD (Verhagen et al, 2013; Van Eerd et al, 2015).
- Interventions to return employees to work following long-term sickness absence due to musculoskeletal disorders were considered cost effective due to the large ongoing costs associated with being on sick leave. Assessed were a workplace intervention, a physical activity and education intervention and a physical activity, education and workplace visit intervention. The workplace intervention was estimated to bear a cost to the employer of £0.34 per day of sick leave avoided (Squires et al, 2012). Assessing the cost effectiveness of interventions on return to work in workers with low back pain has been hampered because of substantial heterogeneity of their effectiveness. However, cost-benefits seem to depend amongst others on timing and duration of the interventions (van Duijn et al, 2010).

Neonatal conditions

No GBD estimate

Overview: Neonatal conditions include adverse pregnancy outcomes like low birth weight, prematurity, intrauterine growth restriction, stillbirth and neonatal sepsis and infections. Congenital malformations are included in the following section on congenital anomalies.

Around 15 million preterm births occur each year which led to around 1 million deaths in 2015 (WHO, 2017w). Preterm birth complications are the leading cause of deaths among children under 5 years of age and are associated with many chronic diseases in later life. Additionally, 3 million stillbirths are thought to occur each year, the great majority in low-income countries (Lawn et al, 2010). The percentage of low birth weight babies ranged broadly between 2–10% in 2012 in different countries but could be much higher in some countries (World Bank, 2017).

Occupation-specific: Higher rates of adverse pregnancy outcomes were observed for mothers exposed to different occupational chemicals (Kumar, 2011; Ferguson et al, 2013; Nieuwenhuijsen et al, 2013). There is accumulating, though still controversial, evidence (El Majidi et al, 2012), for a link between exposure to some endocrine disrupting chemicals, e.g. PCBs and dioxins, and low birth weight and preterm birth (Govarts et al, 2012; Meeker, 2012; Chen Zee et al, 2013; DiVall, 2013; Kishi et al, 2013; Nieuwenhuijsen et al, 2013). Exposure to e-waste as it may occur in recycling workers was also associated with adverse pregnancy outcomes (Grant et al, 2013).

Second-hand tobacco smoke exposure occurs frequently in workplace settings (Jaakkola & Jaakkola, 2006). Second-hand smoking here means second-hand tobacco smoke exposure of the mother and does not include exposure of the foetus from maternal smoking. Second-hand tobacco smoke exposure in non-smoking pregnant women was estimated to increase the risk for stillbirth by around 23% (Leonardi-Bee et al, 2011) and also the risk for low birth weight (Nieuwenhuijsen et al, 2013). The percentage of low birth weight in Japan attributable to second-hand tobacco smoke exposure at home and the workplace was estimated at 16% and 1% respectively (Ojima et al, 2004).

Small increases in risk for preterm birth might exist for long working hours and high physical workload (Palmer, Bonzini, Harris et al, 2013), though overall little to no negative effect on pregnancy outcomes was found for normal job-related activities (Salihu et al, 2012) and it was concluded that associations might be due to confounding factors, chance or bias (Palmer, Bonzini, Bonde et al, 2013). Increased risk for other adverse pregnancy outcomes due to occupational risks is also controversial (MacDonald et al, 2013; Palmer, Bonzini, Harris et al, 2013) and evidence is often lacking. Pregnancy might place women in the workplace under significant psychosocial stress, e.g. from pregnancy-related discrimination, and the association with adverse pregnancy outcomes is still unclear (Mutambudzi et al, 2011; Salihu et al, 2012). However, certain workgroups that predominantly include women of reproductive age are heavily exposed to different chemicals that are suspected to be associated with adverse pregnancy outcomes (Pak et al, 2013).

Additionally, some occupations place pregnant women at increased risk for infections of their unborn child. One such example is cytomegalovirus infection which often occurs in day-care and paediatric settings and which might lead to adverse neurodevelopmental effects such as cerebral palsy, seizures, learning difficulties and hearing loss in the affected child (van Rijckevorsel et al, 2012).

Congenital anomalies

No GBD estimate

Overview: An estimated 6% of global infant deaths are due to congenital anomalies (Higashi et al, 2013). Congenital anomalies include chromosomal conditions, like Down and Edward syndrome, and non-chromosomal conditions, like different congenital organ defects (Loane et al, 2011; WHO, CDC & ICBDSDR, 2014).

Occupation-specific: All following exposures are potentially work related. Evidence on many of these linkages is still limited. Second-hand tobacco smoke exposure in non-smoking pregnant women was estimated to increase the overall risk for congenital malformations, particularly heart defects, limb-reduction defects, kidney/urinary tract defects, and cleft lip and palate defects, by 13% (Leonardi-Bee et al, 2011). There are, furthermore, potential links between prenatal exposure to pesticides, organic solvents and air pollution and congenital heart disease (Vrijheid et al, 2011; Gorini et al, 2014); exposure to some endocrine disrupting chemicals and cryptorchidism and hypospadias (Virtanen & Adamsson, 2012; DiVall, 2013); and pesticide exposure and urinary malformations (Hei & Yi, 2014). Prenatal exposure might further influence male (Meeker, 2012; DiVall, 2013; Vested et al, 2014) and female (Fowler et al, 2012) reproductive health (Snijder et al, 2012).

Examples of occupational or environmental interventions from the epidemiological literature

- Following the smoking ban in bars and restaurants in Norway, children born to female bar and restaurant workers were significantly less often of very low birth weight and significantly less often born preterm (Bharadwaj et al, 2012). Worksite smoking bans were shown to increase tobacco quitting among pregnant women in the United States of America (Adams et al, 2012). In Ireland a workplace smoking ban was associated with significant declines in preterm birth and maternal smoking (Kabir et al, 2009).

Examples of interventions to prevent neonatal conditions and congenital anomalies

Occupations at increased risk include workers exposed to second-hand tobacco smoke and certain chemicals, such as endocrine disrupting chemicals (CDC-NIOSH, 2017).

- Elimination or substitution of reproductive hazards.
- Workplace risk assessment to identify reproductive hazards.
- Engineering and administrative controls to protect all workers, particularly pregnant women, from exposure to reproductive hazards, policies for smoke-free workplaces and worker education and training on healthy work practices.
- PPE.



Exposure to occupational chemicals, such as pesticides, is associated with neonatal conditions and congenital anomalies.

Occupational skin diseases

Occupational skin diseases, mainly contact dermatitis, are among the most commonly reported notifiable occupational diseases (Diepgen, 2012). In Europe, there are approximately 0.5–1 cases of newly reported disease per 1000 workers annually (Diepgen, 2003).

Occupational groups most affected are hairdressers, metal workers, health care workers, food industry workers, construction workers, cleaners and painters (Diepgen, 2012; Behroozy & Keegel, 2014). Preventive measures could avoid a large part of occupational skin diseases and include primarily the removal or replacement of substances such as allergens, followed by reducing their use to avoiding contact, e.g. through ventilation, covers, screens flexible tubing and PPE (De Craecker et al, 2008).

Examples of interventions

Occupations at increased risk include hairdressers, cosmetologists, metal workers, health care workers, food industry workers, construction and agricultural workers, cleaners and painters (CDC-NIOSH, 2013a).

- Elimination or substitution of the hazardous agent.
- Engineering controls, such as local exhaust ventilation or isolation booths.
- Worker education and training.
- PPE.

Other noncommunicable diseases

Outdoor workers (and indoor workers in uncooled workplaces) in hot climates are often exposed to heat stress, which can result in dehydration, fatigue, heat exhaustion, heat stroke and death; and work productivity is also negatively impacted (Marchetti et al, 2016; Nerbass et al, 2017). Increasing temperatures may render substantial parts of the day too hot to work in some areas in the future, with substantial impact on gross domestic product (Kjellstrom et al, 2016). It has been estimated that in South-East Asia between 15–20% of annual work hours might have already been lost due to heat exposure, an estimate that might double by 2050 as a consequence of climate change (Kjellstrom, 2016).

Further links of other noncommunicable diseases to occupational exposure include chronic kidney diseases which have been linked to occupational exposure to lead and cadmium (Muntner et al, 2003; Ekong et al, 2006; Patrick, 2006) and cardiovascular diseases, such as hypertensive heart disease and rheumatic heart disease, which have been linked to lead exposure (IHME, 2016).

There is a range of psychosocial occupational risks with increasing exposure that may detrimentally affect workers' health and well-being, such as job insecurity (Witte et al, 2015), work intensification and high work demands,



Climate change increasingly impacts workers' health and causes lost work hours due to increased daytime temperatures.

Manufactured nanomaterials are increasingly used in manufacturing and industry which may present health hazards to workers. WHO has developed guidelines to protect workers from the potential risks of these materials (WHO, 2017ac).

Examples of occupational or environmental interventions from the epidemiological literature

- Preventing heat-related illness and death in agriculture includes education, monitoring, adjusting rest periods, modifying tools, equipment and processes, designing work assignments to alter heavy and light work and to schedule more strenuous work for cooler hours, providing shade, cooling devices and drinking-water and establishing emergency plans. In the United States of America, California and Washington states have enforced heat illness prevention regulations which include specific requirements for employer provision of drinking-water, shade for rest or other sufficient means to recover from heat, worker and supervisor training and written heat safety plans (Jackson & Rosenberg, 2010).
- The feasibility of the Occupational Safety and Health Administration (OSHA) (United States Department of Labor) Water. Rest. Shade. Programme (OSHA, 2016) has been assessed in sugarcane workers in El Salvador and increased self-reported water consumption, individual daily productivity and decreased symptoms associated with heat stress and dehydration (Bodin et al, 2016).
- Daily aerobic training can help workers to acclimatize to hot working environments as thermoregulatory capacity and blood volume increases. However, in workers needing to wear certain personal protective suits physical activity is not of benefit as the suits hinder the effectiveness of sweating which leads to additional discomfort as sweat accumulates within the suit. For these workers management of working duration and working environment is required (Yamazaki, 2013).



Heat related illness and death in agriculture can be prevented through the provision of drinking-water, rest periods and shade, scheduling heavy work during cooler hours and alterations in heavy and light work.

RISKS FACTORS FOR NONCOMMUNICABLE DISEASES FROM OTHER AREAS BUT RELATED TO THE WORK ENVIRONMENT

Certain risk factors are strongly related to noncommunicable diseases, and can be modulated by favourable working environments. Overweight, obesity and physical activity are examples of such risks which can be influenced by the physical working environment and occupational conditions.

Overweight and obesity

Overview: Overweight refers to a condition of people with a body mass index (BMI) between 25 and 30 kg/m³, and obesity to a condition where BMI is greater or equal 30 kg/m³. In 2016, 39% of adults aged 18 years and above were overweight, and 13% were obese (WHO, 2017s). 41 million children under 5 years were overweight or obese in 2016. Overweight and obesity are major risk factors of noncommunicable diseases such as cardiovascular diseases, diabetes, musculoskeletal disorders and certain cancers (WHO, 2017s).

Occupation-specific: Occupation-related physical activity is an important factor associated with obesity. Demands of physical activity at work were shown to have fallen drastically during the last decades in various regions of the world (Church et al, 2011; Ng et al, 2014). On the basis of a large population survey conducted over decades in the United States of America (United States National Health and Nutrition Examination Survey – NHANES), it was estimated that between 1960–1962 and 2003–2006, the estimated mean daily calorie expenditure has dropped by more than 100 calories per day, which would induce a weight gain of more than 10 kg in certain age groups, corresponding to the weight gain observed during the same period (Church et al, 2011).

Workplaces are settings where interventions promoting healthy diets and physical activity have been effective.



Physical activity at work has fallen drastically, which has been linked to weight gain.

Physical inactivity

Overview: Physical inactivity is an important risk factor for noncommunicable diseases, including IHD and stroke, cancers of the breast, colon and rectum, and diabetes mellitus. Through these diseases, insufficient physical activity is one of the leading risk factors for deaths worldwide (WHO, 2017u). It is estimated that one in four adults is insufficiently active, which is defined as less than 150 minutes of moderate-intensity activity per week, or equivalent (WHO, 2017u). In most regions of the world, inactivity is on the rise (Ng & Popkin, 2012).

Occupation-specific: Development, with the spread of labour-saving technology in the workplace, and the shift away from agriculture to the manufacturing and service sectors, has been contributing to physical inactivity (Ng & Popkin, 2012). In China, for example, mean occupational physical activity has declined by 33% in men and 42% in women, respectively, between 1991 and 2011 (based on data from nine provinces) (Ng et al, 2014). Occupation is the greatest contributor to physical activity in China, accounting for more than 85% of all physical activity in men and 70% in women in 2011. Reduction in occupational physical activity alone has therefore led to an overall reduction of physical activity of 31% in men and 36% in women, respectively, between 1991 and 2011 in China (data from the Chinese Health and Nutrition survey cohort of 22 000 individuals from nine provinces followed over 20 years) (Ng et al, 2014). Occupational factors, such as high job strain or passive jobs, may also lead to less physical activity, suggesting a spill-over effect on leisure-time physical activity (Fransson et al, 2012). In the United States of America the occupational demands on physical activity have dropped significantly during the last decades also (Church et al, 2011).

The workplace environment and occupation-related factors influence physical activity (Kohl et al, 2012; WHO, 2017u). The workplace is therefore an important site for promotion of physical activity (Heath et al, 2012). Promotion of physical activity through occupational health services and work organization was also shown to be promising (Kwak et al, 2014).

Examples of interventions

- Worker education and training.
- Healthy food options at low prices in food service facilities and vending machines.
- Physical activity programmes with inclusion of workers in planning and implementation (WHO, 2009b).

Examples of occupational or environmental interventions from the epidemiological literature

- Workplace health promotion can improve physical activity, dietary behaviour and healthy weight (Schröer et al, 2014). Multi-component programmes in the workplace, including provision of healthy food and beverages at workplace facilities and space and encouragement for fitness, are judged as effective interventions (WHO, 2009b). Additionally, workplace physical activity interventions can improve workers' mental health (Chu et al, 2014).
- Short simple exercise or fitness programmes were shown to be equally effective in, for example, reducing sick leave in workers as more complex and costly interventions (White et al, 2016).
- In the United States of America, a worksite health promotion programme that was introduced by a large company in 1979 and evaluated between 2002–2008. It effectively reduced obesity, high blood pressure, high cholesterol, tobacco use, physical inactivity and poor nutrition and saved between US\$ 1.88–3.92 in medical spending for every US\$ 1 invested in the programme (Henke et al, 2011). This finding is consistent with a systematic review and meta-analysis which found a US\$ 3.27 reduction in medical and US\$ 2.73 in absenteeism costs for every US\$ 1 spent in workplace health promotion programmes (Baicker et al, 2010).

UNINTENTIONAL INJURIES

Road traffic accidents

9.6% (road injuries) attributable to occupational risks (CRA)

Overview: Globally, road traffic injuries are the largest cause of injury deaths, causing more than 1.25 million deaths per year (WHO, 2018b). Almost half of all deaths on the world's roads are among those with the least protection – motorcyclists, cyclists and pedestrians (WHO, 2015a). Key risk factors for road traffic injuries include speeding, alcohol impairment, non-use of helmets, non-use of seat-belts and child restraints, inadequate visibility of pedestrians and other road users, and inadequate enforcement of traffic laws.

Occupation-specific: Work-related road traffic injuries account for an important share of workplace fatalities (WHO & World Bank, 2004). Various factors are associated with increased road traffic injury rates, such as sleepiness, time spent driving, long driving or working hours, occupational stress, alcohol use, medical conditions or excessive speed, and require the attention of occupational health services (Rosso et al, 2006; Robb et al, 2008). Among expatriates (workers working abroad), traffic accidents are among the most important reasons for health care utilization, repatriation or death (Patel, 2011). About 9.6% (6.3–15.1%) of road traffic injuries were attributed to occupational risks in 2015 (IHME, 2016).



Around 10% of road traffic injuries can be attributed to occupational risks.

Examples of interventions

Occupations at increased risk include professional drivers and workers working abroad (CDC-NIOSH, 2013b; 2016; WHO, 2015a).

- Legislation to reduce key risk factors, such as elevated speed, drink-driving and the failure to use seat-belts and helmets.
- Vehicle safety standards such as electronic stability control.
- Administrative controls, such as scheduling work to avoid driving under time pressure or without adequate sleep, implementing adverse weather policies, banning the use of mobile phones while driving and worker education and training such as driver training.

Examples of occupational or environmental interventions from the epidemiological literature

- On-board safety monitoring systems that monitor drivers' performance and behaviour, store data for later review of critical incidents and can provide direct feedback to the driver were shown to potentially reduce risky driving behaviour and reduced involvement in crashes in commercial drivers (Horrey et al, 2012).

Unintentional poisonings

4.7% attributable to occupational exposure to chemicals (CRA)

Overview: Unintentional poisonings are estimated to have caused 108 000 deaths in 2015 (WHO, 2017k). Poisonings considered in this section include poisonings by chemicals or other noxious substances, including drugs, and toxic vapours and gases. Intentional intake of substances or attempted suicides and homicides are covered in other sections.

Occupation-specific: Occupational exposures to heavy metals, pesticides, solvents, paints, cleaning substances, various vapours and gases and other chemicals used in industrial production may occur (Calvert et al, 2008; Begemann et al, 2011; Armenti, 2016). The estimated annual costs of illness of acute poisoning in Nepalese farmers due to the use of pesticides accounted for nearly one third of the total annual health care costs (Atreya, 2008). In the state of Paraná, Brazil, for each US\$ 1 spent on pesticides, approximately US\$ 1.28 may be spent on health care and sick leave due to occupational poisoning (Soares & Porto, 2012). The attribution of unintentional poisonings to occupational exposure to toxic chemicals was estimated to amount to 4.7% (2.7–7.8%) in 2015 (IHME, 2016).



Chemicals are a source of acute poisonings in industry.

Examples of interventions

Occupations at increased risk include agricultural and industrial workers (International Programme on Chemical Safety, 2004).

- Substitution of toxic chemicals by less hazardous substances.
- Engineering controls, such as ventilation and safety devices for adequate storage.
- Administrative controls, such as provision of adequate information about a product's hazards, chemical labelling and worker education and training on correct use.
- PPE, such as gloves, long sleeves, long trousers, boots.

Examples of occupational or environmental interventions from the epidemiological literature

- A systematic review concluded that legislation to ban pesticides might be effective in reducing occupational poisonings in agriculture (Rautiainen et al, 2008).

Falls

8.3% attributable to occupational risks (CRA)

Overview: Globally, falls are the second cause of death from unintentional injuries, with an estimated 646 000 deaths occurring each year. Each year, 37 million falls are severe enough to seek medical attention. A fall is defined as an event where a person comes to rest inadvertently on the ground or lower level. Fatal falls mostly affect adults older than 65 years (WHO, 2017j).

Occupation-specific: Accidental falls may be associated with occupational hazards (WHO, 2017j). Requirements for a safe working environment may include window guards or grab rails, removal of slippery surfaces, adequate lighting and good visibility. Industries and services with the highest risk of occupational falls include the construction industry, manufacturing, buildings and dwellings services, and trade (United States Bureau of Labor Statistics, 2016). Falls due to occupational hazards had an attributable risk factor of 8.3% (5.7–12.4%) in 2015 (IHME, 2016).



Working at height and in construction increases the risk for accidental falls.

Examples of interventions

Occupations at increased risk include industrial and construction workers (CCOHS, 2013; OSHA, 2015).

- Engineering controls, such as window guards, grab rails, safety nets, removal of slippery surfaces, adequate lighting.
- Worker education and training.
- PPE, such as non-slip shoes or work boots and personal fall-arrest systems.

Examples of occupational or environmental interventions from the epidemiological literature

- The Hong Kong (China) Occupational Safety and Health Council has adopted a holistic approach for occupational fall prevention, including scientific research, partnerships with small and medium size enterprises, promotional campaigns for fall prevention and education, and training through courses and workshops. This programme reduced occupational falls from height by 55% and fatal falls by 35% between 1998 and 2012 (Chan & Tang, 2013).
- Higher scaffold height and the absence of a handrail was significantly associated with reduced postural stability and increased cardiovascular stress (assessed as increased heart rate) especially in less experienced construction workers (Min et al, 2012).

Fires, heat and hot substances

8.7% attributable to occupational risks (CRA)

Overview: About 180 000 deaths occur each year due to burns from exposure to fire, heat or hot substances; the vast majority in low- and middle-income countries. Such injuries occur when hot liquids, solids, gases or flames cause injuries to the skin or other tissues. Risk factors for burns include smoking, various environmental risks, occupational exposure to fire and alcohol abuse (WHO, 2017b).

Occupation-specific: Occupational risks affect certain occupations at increased exposure to fire or heat, such as work in accommodation and food services, agriculture, manufacturing and construction industries (Horwitz & McCall, 2004). The global attributable risk for occupational exposure to fire was estimated to amount to 8.7% (5.3–13.9%) in 2015 (IHME, 2016). The occupational fraction of burns treated in emergency departments in high-income countries tends to be much higher (Reichard et al, 2015).



Two firefighters during a training exercise. Worker education and training, and PPE, can protect firefighters from occupational burns.

Examples of interventions

Occupations at increased risk include agricultural, industrial and construction workers, and firefighters (WHO, 2011; 2017b).

- Safety regulations for building design, materials and products.
- Smoke detectors, fire sprinklers and fire-escape systems.
- Worker education and training.
- PPE.

Examples of occupational or environmental interventions from the epidemiological literature

- In the United States of America, an evaluation of a “train the trainer” course on firefighter burn injury awareness training, directed at experienced firefighters and health care providers, increased confidence and awareness of firefighter-specific burn issues among those trained (Kahn et al, 2016).
- The type of PPE can significantly impact burn incidence and severity (Prezant et al, 2000).

Drownings

5.8% attributable to occupational risks (CRA)

Overview: About 360 000 people drown each year (WHO, 2017i). Drowning occurs by respiratory impairment due to submersion/immersion in liquid. The highest drowning rates are among children aged between one and four years (WHO, 2014a; 2017i).

Occupation-specific: Certain occupational activities are at increased risk, e.g. fishing. Waterway transportation on overcrowded or unsafe vessels that lack safety equipment or have insufficiently trained personnel, also increases drowning risks. Strategies to prevent drowning in the workplace include increased awareness and appropriate policies and legislation (WHO, 2014a; 2017i).

The global PAF for occupational risks is 5.8% (3.5–10.2%) in 2015 (IHME, 2016).



Fishermen and other workers on boats, ships and ferries are at risk of drowning, especially when vessels are overcrowded or unsafe, without safety equipment, or personnel are insufficiently trained.

Examples of interventions

Occupations at increased risk include fishermen and workers on boats, ships and ferries (NIOSH, 1994; WHO, 2017x).

- Safe boating, shipping and ferry regulations, such as establishing systems that ensure vessel safety, availability of flotation devices in boats, avoidance of overcrowding, and appropriate travel routes and rules.
- Flood risk management and resilience.
- Engineering controls, such as guard rails on fishing vessels.
- Worker education and training on swimming skills and water safety.
- PPE, such as personal flotation devices.

The development of national water safety plans, and the involvement of other sectors, can further ensure the systematic implementation of sound preventive action.

Other unintentional injuries

- Exposure to mechanical forces: 7.6% attributable to occupational risks (CRA)
- Other unintentional injuries: 5.7% attributable to occupational risks (CRA)

This category includes many different injuries that may occur in a variety of occupational circumstances and workplace settings:

- mechanical forces (e.g. from occupational tools and machinery);
- explosions;
- off-road transportation accidents;
- animal bites, other contact with animals, and contact with venomous animals and poisonous plants;
- exposure to ionizing radiation or electric currents; and
- suffocation.

Occupational injury prevention strategies may include a combination of engineering approaches, education/behavioural interventions and policies or legislation. About 7.6% (4.8–11.9%) of injuries from mechanical forces, and 5.7% (3.5–9.3%) of injuries not classified elsewhere, were attributed to occupational risks in 2015 (IHME, 2016).



Radiation protection officer unloads radioactive equipment for inspection (Kelantan, Malaysia).

Examples of occupational or environmental interventions from the epidemiological literature

- Worksite inspections were shown to decrease injury rates in the long term (Mischke et al, 2013).
- Targeted safety campaigns or drug-free workplace programmes seem to be effective interventions for the prevention of injuries in construction workers (van der Molen et al, 2012).
- Workplace drug testing might deter employees from drug consumption and might lower accident rates. However, the evidence is weak (Pidd & Roche, 2014).
- Nearly 50% of all electrical fatalities in the United States of America between 2003 and 2011 happened in construction workers. A review has therefore assessed current electrical safety training practices in construction and recommends virtual reality simulation for training and testing workers on electrical hazards as a safe tool providing hands-on learning experience (Zhao & Lucas, 2015).
- A systematic review found strong evidence for financial benefits of ergonomic and other musculoskeletal injury prevention interventions in manufacturing and warehousing and system-level disability management interventions in different occupational sectors (Tomba et al, 2009).

INTENTIONAL INJURIES

Self-harm

No GBD estimate

Overview: Close to 800 000 individuals die from suicides annually (WHO, 2018c). Suicide is the second leading cause of death in the 15- to 29-year-old age group. Self-poisoning with pesticides accounts for about one third of the world's suicides, and is the most important means of suicide in India, China and some central American countries, where the majority of pesticide-related suicides occur (Phillips et al, 2002; Gunnell et al, 2007; Patel et al, 2012). Restricted access to means of suicide is effective in preventing suicide, particularly impulsive suicide, where the suicidal crisis is often short-lived (Yip et al, 2012; WHO, 2014c). Individuals tend to have a preference for a given means of suicide. Restriction of one method of suicide only leads to limited substitution by other means (Daigle, 2005).

Occupation-specific: Suicide risks may be increased through difficult working conditions and access to chemicals in the workplace (Jørs et al, 2006; Woo & Postolache, 2008; Patel et al, 2012).

Examples of occupational or environmental interventions from the epidemiological literature

- A comprehensive suicide prevention programme in Montreal, Canada, significantly decreased suicide rates in police by 79%. The intervention consisted of suicide training for all police officers and focused on risk identification and offering help. Additionally, supervisors and union representatives received extended training on suicide risk assessment and helping colleagues in need; a telephone helpline was established and a publicity campaign raised awareness on resources for help and on the importance of working together in suicide prevention (Mishara & Martin, 2012).
- More examples on suicide prevention interventions in the workplace are described in a systematic review, few of them, however, were evaluated on their effectiveness (Milner et al, 2015).

Examples of interventions

- Reduced access to toxic chemicals, e.g. by enforcing regulations on the sale, safer storage and disposal of pesticides.
- Workplace programmes linked to external mental health resources for preventing and reducing job stress, awareness-raising and destigmatization of mental health problems and early detection and treatment of mental health problems (WHO, 2006c; 2014c).



Restricting access to chemicals can prevent suicide.

Interpersonal violence

No GBD estimate

Overview: Nearly half a million people died from interpersonal violence in 2015 (WHO, 2017k). Deaths and injuries are only a fraction of the burden caused by violence, which can result in lifelong consequences on mental health, sexual and reproductive health and chronic diseases (WHO, UNODC & UNDP, 2014). Violence can be influenced by individual, relationship, community and societal risks (WHO, 2004b). Various environmental factors influence interpersonal violence, and interventions in the physical environment could reduce the level of interpersonal violence.

Occupation-specific: Workers in certain occupations or settings, or who perform certain tasks, may be at increased risk of workplace violence or homicide. These may include: a) workers handling money or valuables (cashiers, transport workers); b) workers providing care, advice and education (nurses, teachers); c) workers carrying out inspections or enforcement duties (ticket inspectors, police officers); d) workers in contact with drunk or potentially violent people (prison officers, bar staff); and e) those working alone (taxi drivers) (Jenkins, 1996; Chappell & Di Martino, 2006; ILO, 2009; Edward et al, 2014; Shahzad & Malik, 2014; Pourshakhian et al, 2016). For example, the retail trade and service industries accounted for about half of workplace homicides and 85% of nonfatal workplace assaults in the United States of America (Jenkins, 1996). Also, expatriates, diplomats and volunteers might be at increased risk of experiencing aggression and violence (Patel, 2011).

Exposure to certain substances, such as occupational exposure to lead and other chemicals to women of childbearing age, can negatively impact neuropsychological development and cognitive functioning of their offspring (Axelrad et al, 2007; De Cock et al, 2012; Bergman et al, 2013; Polanska et al, 2013; Grandjean & Landrigan, 2014; Polanska et al, 2014), which has been associated with increased delinquent behaviour (Carpenter & Nevin, 2010).

Examples of interventions

Occupations at increased risk include cashiers, transport workers, health care workers, teachers and police officers (Joint Programme on Workplace Violence in the Health Sector, 2002).

- Engineering and administrative controls, such as safe access to and from the workplace, adequate work space, anti-violence policies, adequate staffing, staff rotation for demanding tasks, work assignments to prevent workers working alone in dangerous situations, worker assistance and counselling and worker education and training on workplace violence.

Examples of occupational or environmental interventions from the epidemiological literature

- Workplace bullying and workplace aggression might be prevented through constructive leadership, perceived organizational support and policies, and training on how to predict, prevent and react to aggression. Guidelines of consequences and interventions to provide targets with assertiveness skills, counselling support and redress are important measures after an event (Dillon, 2012; Kemp, 2014).
- Cash control policies, lighting and working not alone were shown to be effective strategies to reduce workplace violence in small retail businesses (Peek-Asa & Casteel, 2010).



Textile factory in New Delhi, India.

DISCUSSION

This systematic and comprehensive review of the overall impacts of the workplace on health showed that, in 2015, at least 1.2 million deaths were attributable to the workplace, amounting to 2.1% of total deaths in the general population (Table 1). Some 73 million DALYs, a combined measure of years of life

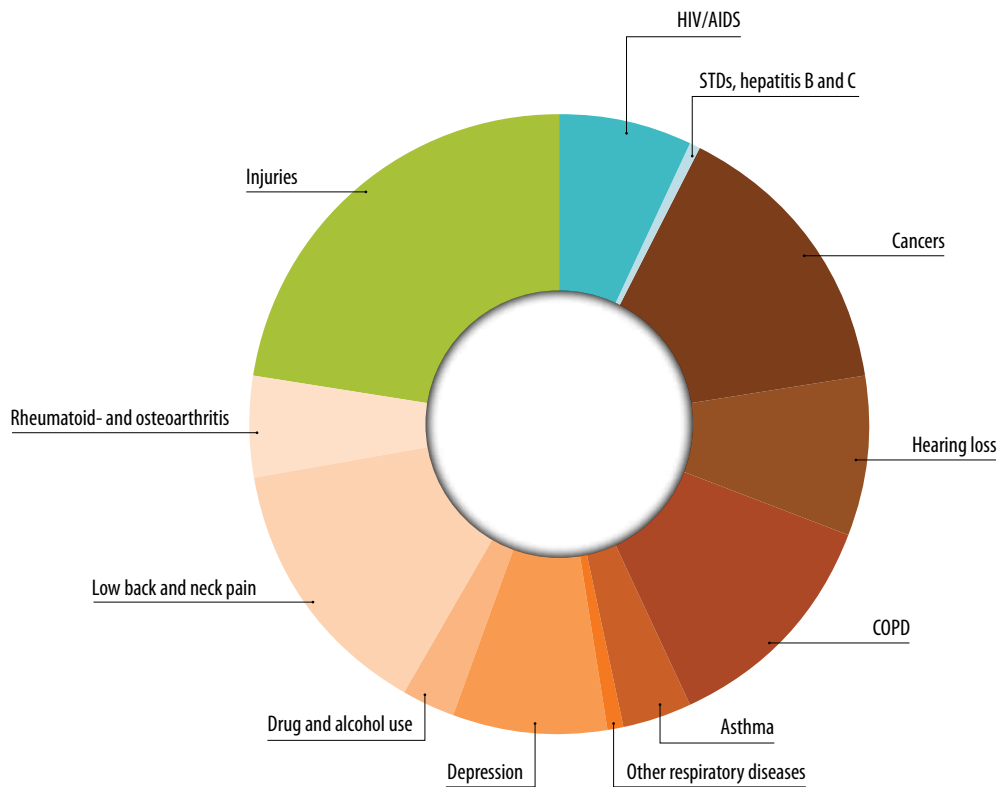
lost due to mortality and disability, were lost, amounting to 2.7% of the global burden of disease. These impacts are a summary of the quantified health impacts to date, but do not account for additional diseases which are currently being evaluated.

Table 1. Population attributable fractions, deaths and disease burden (in DALYs) attributable to occupation, 2015

	PAF (% DALYs, 95% CI)	Deaths	DALYs	Method
Total deaths/DALYs (in total population)		56 441 319	2 668 295 399	
Total occupational deaths/DALYs		1 213 193	73 100 660	
Burden attributable to occupation		2.1%	2.7%	
Infectious and parasitic diseases				
HIV/AIDS	8.2 (6.0, 10.5)	92 880	5 129 333	Limited epidemiological data
Sexually transmitted diseases¹	3.0 (1.5, 6.1)	682	325 359	Limited epidemiological data
Hepatitis B	2.1 (0.6, 4.2)	1773	74 789	Limited epidemiological data
Hepatitis C	0.4 (0.3, 0.6)	14	521	Limited epidemiological data
Noncommunicable diseases				
Cancers				
Trachea, bronchus and lung cancer	24.6 (21.1, 28.4)	438 352	10 112 272	CRA
Mesothelioma	63.5 (49.0, 76.5)	17 606	362 196	CRA
Larynx cancer	8.6 (3.8, 15.3)	8248	223 810	CRA
Nasopharynx cancer	1.7 (0.06, 4.2)	840	32 494	CRA
Kidney cancer	0.1 (0.03, 0.2)	215	5696	CRA
Ovarian cancer	0.5 (0.2, 1.0)	1299	26 925	CRA
Leukaemia	2.1 (1.0, 3.6)	5564	233 544	CRA
Hearing loss	25.3 (22.0, 29.3)	0	6 094 498	CRA
COPD	12.3 (5.8, 19.2)	325 087	8 989 243	CRA
Asthma	9.7 (5.1, 14.6)	37 809	2 643 317	CRA
Other respiratory diseases²	5.6 (3.0, 6.8)	21 497	577 715	CRA
Mental, behavioural and neurological disorders				
Depression	10.9 (4.4, 30.7)	0	5 893 527	Expert opinion 2015
Drug and alcohol use	15.8 (5.9, 37.6)	20 562	2 068 239	Expert opinion 2015
Musculoskeletal diseases				
Low back and neck pain	19.6 (14.7, 24.9)	0	10 201 779	CRA
Rheumatoid arthritis	16.5 (5.8, 30.0)	8123	1 125 192	Expert opinion 2005
Osteoarthritis	19.9 (10.9, 28.8)	0	2 558 085	Expert opinion 2005
Unintentional injuries				
Road injury	9.6 (6.3, 15.1)	118 867	7 309 969	CRA
Poisonings	4.7 (2.7, 7.8)	4769	307 835	CRA
Falls	8.3 (5.7, 12.4)	27 300	2 616 673	CRA
Fire, heat and hot substances	8.7 (5.3, 13.9)	13 495	1 044 907	CRA
Drownings	5.8 (3.5, 10.2)	22 507	1 308 489	CRA
Exposure to mechanical forces	7.6 (4.8, 11.9)	13 515	1 152 469	CRA
Other unintentional injuries	5.7 (3.5, 9.3)	32 189	2 681 784	CRA

Notes: CI: confidence interval; ¹ excludes HIV/AIDS; ² includes pneumoconiosis.

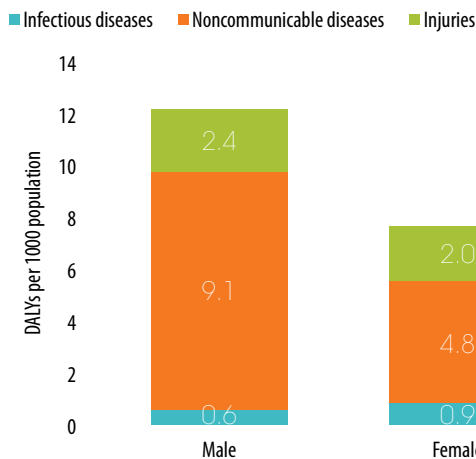
Figure 1. Total disease burden (in DALYs) attributable to occupational risks, by disease, 2015



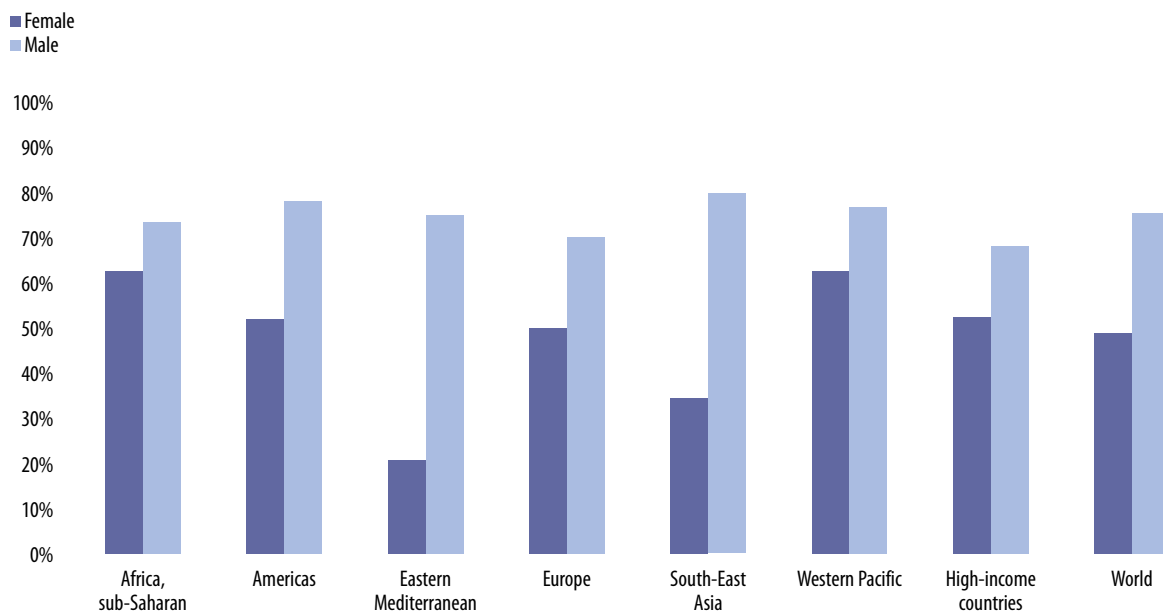
Noncommunicable diseases contribute 70% to the total disease burden from occupational risks (Figure 1). Men are disproportionately affected by occupational disease burden (Figure 2), mainly because of a substantially larger labour participation rate of males compared with females (75% versus 49% ages 15+ in 2015) (Figure 3). Women, on the other hand, are more often in vulnerable

forms of employment and usually have more restricted access to quality employment, are less eligible for social protection, and receive lower levels of remuneration than their male counterparts (ILO, 2018b). Workers in low- and middle-income countries usually suffer from higher occupational disease burden than workers in high-income countries (Figure 4). These estimates focus on reasonably modifiable occupational risks and data from intervention studies – the results, therefore, indicate the potential burden of disease that could reasonably be prevented by occupational interventions (listed under each disease section and in Table A1 of the Annex).

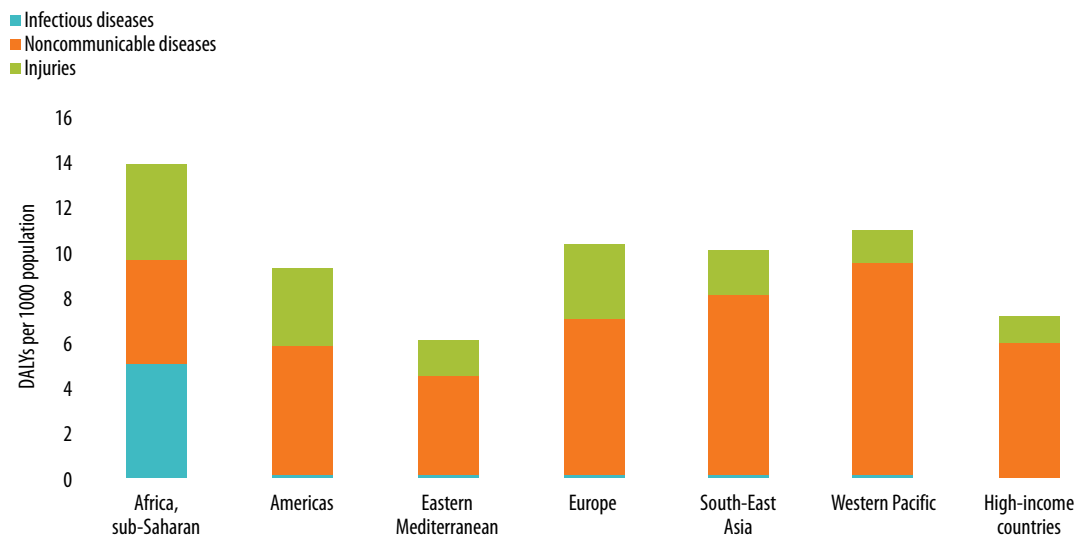
Figure 2. Total disease burden (in DALYs per 1000 population) attributable to occupational risks, by sex and disease group, 2015



Cost-effective occupational health interventions can make a valuable and sustainable contribution towards reducing the global disease burden and improving the well-being of people everywhere. Many of these interventions will have co-benefits beyond improving workers’ health, such as helping to alleviate poverty and reduce gender inequalities.

Figure 3. Labour force participation rate, by region and sex, 2015

Note: High-income countries are listed separately, the remaining regions contain low- and middle-income countries only.
Source: Data taken from ILO, 2018a; World Bank, 2018.

Figure 4. Total disease burden (in DALYs per 1000 population) attributable to occupational risks, by region and disease group, 2015

Note: High-income countries are listed separately, the remaining regions contain low- and middle-income countries only.

Strength of evidence and methods used:

This analysis combines estimates from various sources and various types of assessments, ranging from CRA-type analyses to approximate epidemiological estimates and standardized surveys of expert opinion. Where general, quantified exposure-response functions and sufficient global exposure information were available, CRA estimates

were generally used (Table 1). Where approximate epidemiological estimates or expert surveys were used to estimate the PAFs, the body of evidence was usually more limited. The evidence varies in strength across risk factors and diseases. The results rely on various degrees of assumptions across diseases, while reflecting the current state of knowledge. Occupational fractions

of disease burden are calculated and presented for the total general population. Had we only looked at the adult working population, fractions of disease burden attributable to occupation would usually be higher.

Economic evaluations listed throughout this report do not apply standardized methodologies and results across studies can therefore not be compared. It is recommended that in case readers plan to use or cite the results of a particular study or intervention cited in this report, readers go back to the primary studies to check and understand the applied methodology.

Limited accounting for certain diseases and risks:

Only a fraction of occupational risks and related diseases is quantified for burden of disease estimation. Diseases with a potentially high contribution in occupational disease burden that are not covered include cardiovascular diseases such as IHD and stroke and vector-borne diseases such as malaria and dengue. Furthermore, occupational diseases, injuries and deaths are probably subject to substantial underreporting due to poor data collection, incentives for non-reporting, long latency periods between exposure and disease such as for cancer, workplace-health associations that are not immediately obvious (such as lead exposure and hypertension) and the large share of the informal sector (Perry & Hu, 2010).

There are many examples of occupational risks that have not been adequately evaluated, including the effects of emerging risks (e.g. more intensive agricultural practices and zoonoses), the effects of many long-term chemical exposures on cancers or endocrine disorders, and the impact of electromagnetic and other exposures from new technologies. Finally, the potentially very wide-ranging health impacts from climate change, many of them being indirect, will unfortunately not be captured by an assessment using the methods applied here. It is therefore likely that our analysis underestimates the global burden of disease attributable to reasonably

modifiable occupational causes. On the other hand, occupation has numerous positive effects on people's health and well-being which are not accounted for in this analysis.

Applicability: It is important to remember that the resulting PAF is a mean value and is not applicable to any individual country, particularly as the associated risks vary significantly from country to country.

THE WORKPLACE, HEALTH AND THE SUSTAINABLE DEVELOPMENT GOALS

Given the multiple linkages between the working environment and health in the Sustainable Development Goals (SDGs), creating healthy workplaces will be a prerequisite to the attainments of SDGs, in particular, SDG 1 – end poverty in all its forms everywhere; SDG 3 – ensure healthy lives and promote well-being for all at all ages; and SDG 8 – promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.

Goal 1: End poverty in all its forms everywhere

Elimination of extreme poverty is the overarching theme of the SDGs and the target of the first goal. Occupational risks disproportionately affect the poor and those residing in lower income countries (Figure 4). This may be due to lower protection of workers or the large share of migrant and informal workers. Common characteristics of informal employment are lack of protection in the event of non-payment of wages, layoffs without notice or compensation, unsafe working conditions and the absence of social benefits such as pensions, sick pay and health insurance – all of which can favour and sustain poverty. Occupational risks can lead to and aggravate poor health, which further precipitates people into poverty. The impacts of unhealthy working conditions can result in increased health care expenditures

and lost productivity and income. This study corroborates these associations, with generally higher per capita occupational disease burden (as expressed in DALYs) in poorer regions compared with wealthier ones for many of the diseases (Figure 4, Tables A2 and A3 of the Annex list deaths and DALYs by region and income status). Therefore, reducing occupational risks, particularly in vulnerable populations, is likely to make an important contribution to poverty reduction.

Goal 3: Ensure healthy lives and promote well-being for all at all ages

This study estimates that at least 2.7% of the global disease burden (in DALYs) is attributable to modifiable occupational risks to health. Occupational risks affect particularly the working-age period (mainly 15 to 64 years of age, sometimes beyond) which covers a large part of people's lifespan. Health effects from occupational exposures are, however, sustained in older age, and babies and children can be affected through certain parental exposures. Satisfying and healthy working conditions are crucial components to assure people's quality of life and majorly impact mental and physical health. Reducing occupational health risks is therefore an essential step for achieving this goal.

Goal 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all

Workers' health and productivity, dependent on a safe living and working environment, are vital ingredients for economic growth. Working conditions are a major determinant of people's health, well-being and income opportunities. Occupational health services can make important contributions to protect workers' health with regards to occupational risks but also the general health of workers. Women should receive the same opportunities for quality employment, social protection and levels of remuneration as their male counterparts. Worksites will also need to take into account the challenges and opportunities of an ageing workforce. Older workers might be more vulnerable to injuries and musculoskeletal disorders but bring along increased experience. Older workers need to be protected, and hiring and employment practices made equitable regardless of age.



Sustainable Development Goal 8 calls for full and productive employment and decent work for all women and men.

CONCLUSIONS: TOWARDS HEALTHIER AND SAFER WORKPLACES

KEY FINDINGS

Occupational risks account for a large fraction of the global disease burden:

Across the total population, at least 2.1% of all deaths worldwide and 2.7% of all DALYs are attributable to the working environment. Reducing occupational exposures would considerably reduce the global burden of disease.

The SDGs are closely interlinked with occupational health:

The working environment directly influences health and sustainable development in many ways, acting through harmful exposures and poor working conditions, which often disproportionately affect the poor and poorer countries, and also through positive effects on people's quality of life and self-esteem. Adverse occupational conditions can lead to poorer health, and poor health can precipitate people into poverty through increased health care expenditures, loss of shelter, lost income, or increased expenditure to compensate for inadequate services. On the other hand, occupational health services can make important contributions to protect workers from occupational risks and promote workers' health in general, and sometimes reach population groups which would not otherwise have had adequate access to health care. The link between occupational health and the SDGs shows that improving occupational conditions for health is going to be an important element in progressing towards the SDGs.

The disease burden from occupational risks is mainly from noncommunicable diseases:

Reducing occupational risks would have the greatest effect on reducing noncommunicable diseases. Some 51 million out of 73 million DALYs caused by occupational risks are noncommunicable diseases (Table 1, Figure 1).

A large part of the population is directly affected by occupational risks:

Around 62% of the population above 15 years is economically active. A large proportion of one's lifetime is spent in the workplace, leading to potentially long-term and continuous exposures. Special challenges to occupational health include the large share of informal workers and the increasing impacts of an ageing workforce. Occupational risks are disproportionately large in specific countries and in certain occupations such as mining, construction and agriculture and affect mainly lower socioeconomic groups. However, "new" occupational and work-related diseases, such as work-related stress and health effects from different chemicals, complement the more traditional risks.

Recognizing the important burden of disease linked to occupational risks and being able to point to the main areas of concern is of great significance. Given that much of this burden is preventable, although not always with immediately implementable and cost-effective interventions, working to reduce occupational health risks will greatly improve our health.

REDUCING THE BURDEN OF UNHEALTHY WORKPLACES

In order to protect and promote the health of all workers, the 60th World Health Assembly (2007) urged countries:

- To devise, in collaboration with workers, employers and their organizations, national policies and plans for workers' health, and to establish mechanisms and legal frameworks for their implementation, monitoring and evaluation.
- To work towards full coverage of all workers, including those in the informal economy, small- and medium-sized enterprises, agriculture, and migrant and contractual workers, with essential interventions and basic occupational health services for primary prevention of occupational and work-related diseases and injuries.
- To establish and strengthen core institutional capacities and human resource capabilities for dealing with the special health needs of working populations and to generate evidence on workers' health and translate that evidence into policy and actions.
- To develop guidelines for providing health services and surveillance mechanisms for human and environmental hazards and diseases introduced into local communities where mining, other industrial and agricultural activities have been set up to meet the associated needs of those communities.
- To ensure collaboration and concerted action by all national health programmes relevant to workers' health, such as those dealing with prevention of occupational diseases and injuries, communicable and noncommunicable diseases, health promotion, mental health, environmental health, and health systems development.

- To encourage incorporation of workers' health in national and sectoral policies for sustainable development, poverty reduction, employment, trade, environmental protection and education.
- To facilitate the development of effective mechanisms for collaboration and cooperation between developed and developing countries at regional, subregional and country levels in implementing action on workers' health.
- To encourage the development of comprehensive health and non-health strategies to ensure reintegration of sick and injured workers into mainstream society, in coordination with different government and nongovernmental organizations (WHO, 2007c).

Many occupational exposures are preventable with feasible and cost-effective interventions. Sufficient evidence exists that primary prevention is highly effective, for example, in reducing occupational cancer (Espina et al, 2013). The workplace should be viewed as a key element for health protection and health promotion that consequently supports the reduction of health inequalities. Additionally, a comprehensive approach is needed for early identification, assessment and management of health impacts in workplaces.

Current and future challenges include a large informal and an increasingly ageing workforce, improving understanding about work-related mental health issues, and emerging health effects from various chemicals such as manufactured nanomaterials and persistent organic pollutants. Not all occupational hazards to human health are equally understood and it is essential to continue building our understanding. Trusted facts about health and the working environment can lead to the best possible decisions to protect people from occupational health risks.

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ANNEX

METHODS: ESTIMATING THE OCCUPATIONAL BURDEN OF DISEASE

What is meant by the population attributable fraction of a risk factor?

The PAF is the proportional reduction in death or disease that would occur if exposure to a risk were removed or reduced to an alternative (or counterfactual) exposure distribution. In this study, the occupational risks were considered to be reduced to minimum exposure distributions that are currently achieved in certain population groups or that could be achieved by certain changes in the workplace.

A first issue is the establishment of a realistic minimum exposure level. The simplest case of an alternative distribution of exposure to the risk factor is that where the exposure can be reduced to zero, but this is not always achievable in practice. For this reason, this analysis considers how much disease burden would decrease if exposure to a risk factor were reduced, not to zero, but to some achievable level (the counterfactual or baseline level).

The occupational disease burden is often the result of diverse environmental, social and behavioural risk factors. The sum of the PAFs of these separate risk factors, as estimated in many CRAs, may add up to more than 100% – meaning that the disease burden could be potentially reduced or eliminated by tackling different risk factors.

Calculation of population attributable fractions

A generalized PAF can be calculated for an exposure distributed continuously across the study population (Ezzati et al, 2003):

$$\text{PAF} = \frac{\int_{x=0}^m RR(x)P(x)dx - \int_{x=0}^m RR(x)P'(x)dx}{\int_{x=0}^m RR(x)P(x)dx}$$

Where:

x = Exposure level.

$P(x)$ = Population distribution of exposure.

$P'(x)$ = Alternative (“counterfactual”) population distribution of exposure.

$RR(x)$ = Relative risk at exposure level x compared with the reference level.

M = Maximum exposure level.

When the exposure becomes a categorical variable, the formula for the PAF gets simplified:

$$PAF = \frac{\sum P_i RR_i - \sum P_i' RR_i}{\sum P_i RR_i}$$

Where:

PAF = Population attributable fraction.

P_i = Proportion of the population in exposure category i .

P_i' = Proportion of the population in the alternative exposure category i .

RR_i = Relative risk at exposure category i compared with the reference level.

If the risk factor were to be completely removed, or if exposed populations were to be compared with unexposed populations, the burden of disease reduction can be calculated from a simplified form of the above formula:

$$PAF = \frac{\sum P_i RR_i - 1}{\sum P_i RR_i}$$

Estimating the population attributable fraction

To estimate comprehensive health impacts of occupational risks worldwide, available CRAs were combined for each disease, and were complemented with approximate epidemiological estimates and surveys of expert opinion. For each of the diseases and injuries listed in the WHO Global Health Observatory for 2015 (WHO, 2017k), representing the entire disease burden, the literature was systematically searched to identify the best available evidence of population health impacts from occupational risks. Diseases, injuries and their groupings were classified according to the International Classification of Diseases (WHO, 2015b).

The results of the literature review were used to compile quantitative estimates and summaries of links between diseases and injuries and the workplace, using the following order of priority for each disease:

1. Global estimates (such as CRAs) of population impacts for occupational risks.
2. National or regional estimates of population impacts.
3. Results of systematic reviews and meta-analyses on disease reduction from interventions or on occupational determinants.
4. Individual studies on interventions and occupational determinants.

Three different approaches were used to arrive at estimates of the fractions of disease attributable to occupational risks, according to available estimates and the type and amount of evidence available on exposure and exposure-risk relationships. In order of priority, the following approaches were applied to each disease:

- CRA – estimates resulting from this approach were used if available. CRA methods generally provide estimates based on the strongest evidence and most comprehensive data.
- Calculation based on limited exposure and/or epidemiological data.
- Expert survey – expert surveys were used when CRAs were not available, and exposure information and/or exposure-risk relations from limited epidemiological data were insufficient.

Comparative risk assessment

Whenever available, CRA methods were used. These methods use: a) detailed population exposure data; b) an alternative (counterfactual) exposure distribution to which occupational risks could be reduced; and c) matching exposure-risk relationships for the global population. For each disease, these data are combined into PAFs. Furthermore, a set of basic criteria was used for selection of exposure-disease pairings, for the definition of alternative (counterfactual) exposure distribution, as well as the selection of exposure and exposure-risk data used. Detailed methods are described elsewhere (Ezzati et al, 2002; Prüss-Ustün et al, 2003; WHO, 2009a; Lim et al, 2013).

Calculations based on limited epidemiological data

In cases where: a) limited exposure information was available; b) data on prevalence of disease in high-risk population were available; or c) outcomes could in part be attributed to certain occupational conditions; then PAFs could also be estimated, but were generally based more on assumption and extrapolation and, presumably, weaker evidence.

Expert survey

Where neither CRA at the global level, nor sufficient data to perform approximate calculations of PAFs based on more limited evidence were available, then a survey of experts was performed. Three or more experts were consulted to provide their estimates of the PAF for one or more disease or injury.

These experts were selected on the basis of their publication record, preferably international in scope, in the area of the disease or the relevant occupational risk factor. A geographical balance was sought in their selection, in particular for diseases involving environmental risks with strong regional variation. The experts were provided with abstracts of search results from the systematic reviews, as well as an initial estimate that was based on pooled estimates from the literature. CRA results also often provided partial results for a disease and a corresponding attributable risk.

Experts were asked to provide a best estimate of the fraction of disease in the global population attributable to occupation, as well as the 95% confidence interval (CI). Experts were free to provide different estimates by age, sex and region. Each expert reply was assumed to have a triangular probability distribution. The probability distributions of all expert replies for each disease were summed to determine a pooled probability distribution:

$$P_{PAF} = \frac{\sum_{E=1}^n p_{PAF}}{n}$$

Where:

PAF = Population attributable fraction.

P = Resulting probability at attributable fraction PAF.

p = Probability of individual expert at attributable fraction (AF).

E = Expert.

The resulting mean PAF was defined as the overall best estimate. A new 95% CI was defined as ranging from the 2.5 to the 97.5 percentiles of the pooled probability distribution of all the experts. This method can lead to relatively large CIs. Therefore, if an expert estimate did not overlap with any of the other expert estimates, this outlying best estimate was used to define the boundary of the pooled estimate, rather than the CI from the expert survey. Pooled estimates were calculated by generating 2000 draws of each distribution, and 95% intervals were defined by the 2.5 and the 97.5 percentiles.

Where the body of evidence resulting from the updated literature review did not substantially differ or was unlikely to justify a change in expert estimation of PAF, the results of the expert survey of the 2006 edition of the report *Preventing disease through healthy environments* (Prüss-Ustün & Corvalán, 2006) were used. Certain diseases or occupational risk factors were not included in the analysis, either because there was insufficient evidence at the global level or because the risk factor resulted in a relatively small disease burden.

Estimating the burden of disease attributable to the environment

To calculate the fraction of disease attributable to a risk factor for any defined population, compiled or estimated PAFs were multiplied by the corresponding WHO disease statistics (WHO, 2015b), by disease or injury, country, sex and age group, for deaths and DALYs. The following equations were used:

$$AM = PAF \times M$$

and

$$AB(DALYs) = PAF \times B(DALYs)$$

Where:

AM = Attributable mortality.

PAF = Population attributable fraction.

M = Mortality.

AB (DALYs) = Attributable burden in DALYs.

B (DALYs) = Burden of disease in DALYs, for each disease or injury, country, sex and age group, where relevant.

Estimating uncertainties

Every estimate of a PAF was characterized by a best estimate and a CI, whether based on CRA, limited epidemiological evidence or on expert surveys. The upper and lower estimates of the attributable disease burden were defined as the 2.5 and 97.5 percentiles of 2000 draws using those distributions.

More information on the methodology can be found in the technical appendix in the 2016 edition of the report *Preventing disease through healthy environments* (Prüss-Ustün et al, 2016).

Table A1. Examples of interventions for worker protection

Disease	Examples of occupations at increased risk	Examples of interventions
Infectious and parasitic diseases		
Respiratory infections	Health care workers	Engineering controls: adequately ventilated single rooms, UVGI for disinfection of air; administrative controls: clinical triage and separation of patients, patient cohorting, vaccination; PPE
Intestinal infections	Agricultural workers, miners in endemic settings	Vector control and reduced vector contact through for example safe drinking-water and sanitation facilities at work; periodic medicinal treatment; worker education and training; PPE
Malaria	Agricultural and migrant workers in endemic settings	Vector control through environmental management and safe sanitation, water management and drainage; worker education and training; PPE
Schistosomiasis	Fishermen, agricultural and irrigation workers in endemic settings	Vector control through environmental management; access to safe sanitation; preventive chemotherapy; worker education and training
Chagas disease	Agricultural and migrant workers, workers residing and working in endemic settings, laboratory personnel (handling Chagas infected material)	Vector control through environmental management; worker education and training; housing and food hygiene; PPE
Lymphatic filariasis	Agricultural workers in endemic settings	Vector control through, for example, safe sanitation and water management; PPE
Onchocerciasis	Agricultural workers in endemic settings	Vector control through environmental management; community-directed treatment with ivermectin; PPE
Leishmaniasis	Agricultural workers in endemic settings	Vector control through environmental management; worker education and training; PPE
Dengue	Agricultural and migrant workers in endemic settings	Vector control through environmental management, disposing waste properly, removing artificial habitats and covering, emptying and cleaning of domestic water storage containers; PPE
Japanese encephalitis	Agricultural workers in endemic settings	Vector control through environmental management and integrated vector management; vaccination; improved pig husbandry; PPE
HIV/AIDS	Sex workers the uniformed workforce, the military, miners, truck drivers, migrant workers, seafarers and fishermen Health care workers	Pre-exposure prophylaxis (PrEP) for workers at substantial HIV risk; post-exposure prophylaxis (PEP); harm reduction interventions for substance use; worker education and training; correct and consistent use of condoms with condom-compatible lubricants PEP; worker education and training; PPE and safe needle technology
Sexually transmitted diseases	Sex workers the uniformed workforce, the military, miners, truck drivers, migrant workers, seafarers and fishermen	Worker education and training; correct and consistent use of condoms
Hepatitis B and C	Health care workers	Hepatitis B vaccination; post-exposure management/prophylaxis; worker education and training; PPE and safe needle technology
Tuberculosis	Health care workers	Engineering controls: adequate ventilation, UVGI; TB surveillance among health care workers; administrative controls: triage and separation of patients, worker and patient education and training; PPE
Noncommunicable diseases		
Cancers	Workers exposed to industrial or agricultural carcinogens or to radiation	Regulation/standards to reduce carcinogens at the workplace; engineering controls: capsulation and closed processes; monitoring of workers' exposure; administrative controls: policies for smoke-free workplaces, access to healthy food and promotion of physical activity, worker education and training; PPE
Mental, behavioural and neurological disorders		Health and safety policies and practises for identifying distress, harmful use of psychoactive substances and illness and for providing resources and support to manage them, involvement of employees in decision-making, organizational practices supporting a healthy work-life balance, programmes for employee career development and recognition of employee contribution
Cataracts	Outdoor workers and welders with ultraviolet light exposure	Engineering controls: equipment to shield the welding workplace; administrative controls: reducing time in the midday sun, worker education and training; PPE
Hearing loss	Miners, manufacturing and construction workers	Engineering controls for noise reduction; administrative controls: limiting the time in noisy environments; PPE

Disease	Examples of occupations at increased risk	Examples of interventions
Cardiovascular diseases (IHD and stroke)	Industrial and construction workers in settings where lead is being used, emergency responders such as police and firefighters and workers exposed to shift work and high job strain	Replacement of lead-containing products; engineering controls: ventilation; blood lead monitoring of exposed workers; worker education and training; PPE Public health interventions not specific to the working population: tobacco control policies, promotion of foods low in fat, sugar and salt and of physical activity, strategies to reduce harmful use of alcohol
Chronic obstructive pulmonary disease	Agricultural workers, construction workers, miners, welders, workers in the rubber or plastics industry	Engineering controls: physical containment or segregation of the emission source, ventilation systems and dust suppression techniques; policies for smoke-free workplaces
Asthma	Workers exposed to allergens and irritants at work such as cleaning agents, disinfectants, isocyanides, enzymes, coffee, flour, animals and green house allergens, wood dust, colophony, latex and metals	Elimination or substitution of processes or materials; engineering controls: enclosed processes and local exhaust ventilation; administrative controls: policies for smoke-free workplaces, safe work practices, exposure reduction and prevention, worker education and training
Pneumoconiosis	Miners, industrial and construction workers with exposure to asbestos and silica and coal dust	Elimination or substitution of processes or materials; engineering controls: enclosed processes, local exhaust ventilation and dust suppression techniques; administrative controls: work practices or policies for exposure reduction and prevention; worker education and training; PPE
Musculoskeletal diseases	Agricultural and forestry workers, fishermen, production and service workers	Engineering controls: automation and mechanisation, ergonomic workplace design, work equipment and tools; ergonomic risk assessment; administrative controls: adequate staffing levels, job enlargement and rotation, working hours and breaks, worker education and training; PPE
Neonatal conditions and congenital anomalies	Workers exposed to second-hand tobacco smoke and certain chemicals	Elimination or substitution of reproductive hazards; workplace risk assessment; engineering and administrative controls to protect all workers and, in particular, pregnant women from exposure to reproductive hazards, policies for smoke-free workplaces, worker education and training; PPE
Occupational skin diseases	Hairdressers, cosmetologists, metal workers, health care workers, food industry workers, construction and agricultural workers, cleaners and painters	Elimination or substitution of the hazardous agent; engineering controls: local exhaust ventilation or isolation booths; worker education and training; PPE
Overweight, obesity and physical inactivity		Worker education and training; healthy food options at low prices in food service facilities and vending machines; physical activity programmes with inclusion of workers in planning and implementation
Injuries		
Road traffic injuries	Professional drivers, workers working abroad	Legislation to reduce key risk factors such as elevated speed, drink-driving and the failure to use seat-belts and helmets; vehicle safety standards such as electronic stability control; administrative controls: scheduling work to avoid driving under time pressure or without adequate sleep, implementing adverse weather policies, banning the use of mobile phones while driving and worker education and training such as driver training
Unintentional poisonings	Agricultural and industrial workers	Substitution of toxic chemicals by less hazardous substances; engineering controls: ventilation and safety devices for adequate storage; administrative controls: provision of adequate information about a product's hazards, chemical labelling and worker education and training on correct use; PPE
Falls	Industrial and construction workers	Engineering controls: window guards, grab rails, safety nets, removal of slippery surfaces, adequate lighting; worker education and training; PPE
Fire, heat and hot substances	Agricultural, industrial and construction workers, firefighters	Safety regulations for building design, materials and products; smoke detectors, fire sprinklers and fire-escape systems; worker education and training; PPE
Drownings	Fishermen, workers on boats, ships and ferries	Safe boating, shipping and ferry regulations; flood risk management and resilience; engineering controls such as guard rails; worker education and training; PPE
Self-harm		Regulations to reduce access to toxic chemicals; workplace programmes linked to external mental health resources for preventing and reducing job stress, awareness-raising and destigmatization of mental health problems and early detection and treatment of mental health problems
Interpersonal violence	Cashiers, transport workers, health care workers, teachers and policemen	Engineering and administrative controls: safe access to and from the workplace, adequate work space, anti-violence policies, adequate staffing, staff rotation for demanding tasks, work assignments to prevent workers working alone in dangerous situations, worker assistance and counselling and worker education and training on workplace violence

Table A2. Deaths attributable to occupation, by region, 2015

	Africa ¹	Americas		Eastern Mediterranean	
		HIC	LMIC	HIC	LMIC
Population	993 162 813	379 204 188	603 571 688	52 700 445	603 491 438
Total deaths	9 207 248	3 084 572	3 519 556	149 560	3 889 851
Total occupational deaths	183 300	53 498	78 303	2545	39 360
Burden attributable to occupation	2.0%	1.7%	2.2%	1.7%	1.0%
Infectious diseases					
HIV/AIDS	86 899	22	1529	1	240
Sexually transmitted diseases ²	342	15	50	1	32
Hepatitis B	474	0	38	0	96
Hepatitis C	3	0	1	0	1
Noncommunicable diseases					
Cancers					
Trachea, bronchus and lung cancer	5492	32 534	22 275	713	9344
Mesothelioma	312	2870	460	12	208
Larynx cancer	384	263	1389	22	618
Nasopharynx cancer	58	2	11	3	31
Kidney cancer	7	9	36	2	13
Ovarian cancer	117	89	142	1	56
Leukaemia	508	146	671	41	435
Hearing loss	0	0	0	0	0
COPD	16 208	7546	14 804	231	11 728
Asthma	9583	217	613	48	2229
Other respiratory diseases ³	607	1203	1021	26	415
Mental, behavioural and neurological disorders					
Depression	0	0	0	0	0
Drug and alcohol use	1829	1723	2949	22	298
Musculoskeletal diseases					
Low back and neck pain	0	0	0	0	0
Rheumatoid arthritis	229	504	563	4	79
Osteoarthritis	0	0	0	0	0
Unintentional injuries					
Road injury	29 368	3865	20 224	993	7262
Poisonings	1537	88	151	3	226
Falls	4935	858	2463	139	743
Fire, heat and hot substances	4659	233	728	45	583
Drownings	5025	357	2321	60	1670
Exposure to mechanical forces	4610	201	1241	74	666
Other unintentional injuries	10 114	754	4624	105	2387

Notes: HIC: high-income countries; LMIC: low- and middle-income countries; ¹ contains Seychelles; ² excludes HIV/AIDS; ³ includes pneumoconiosis.

Europe		South-East Asia	Western Pacific		
HIC	LMIC		HIC	LMIC	
502 352 344	410 632 000	1 926 539 250	212 935 516	1 658 379 125	Population
4 812 378	4 466 178	13 836 117	1 968 237	11 507 622	Total deaths
88 975	57 664	294 282	32 813	382 452	Total occupational deaths
1.8%	1.3%	2.1%	1.7%	3.3%	Burden attributable to occupation
Infectious diseases					
23	298	2844	3	1021	HIV/AIDS
23	32	139	14	35	Sexually transmitted diseases²
1	22	972	0	169	Hepatitis B
0	0	7	0	2	Hepatitis C
Noncommunicable diseases					
Cancers					
62 065	21 844	45 993	21 550	216 544	Trachea, bronchus and lung cancer
8554	1248	183	2023	1735	Mesothelioma
714	563	2197	134	1966	Larynx cancer
3	10	180	14	527	Nasopharynx cancer
11	14	26	5	92	Kidney cancer
298	139	133	44	280	Ovarian cancer
153	198	1036	81	2295	Leukaemia
0	0	0	0	0	Hearing loss
4277	7761	153 022	4947	104 564	COPD
115	500	19 646	111	4747	Asthma
3053	601	4705	1925	7941	Other respiratory diseases³
Mental, behavioural and neurological disorders					
0	0	0	0	0	Depression
3082	5473	2322	285	2579	Drug and alcohol use
Musculoskeletal diseases					
0	0	0	0	0	Low back and neck pain
710	83	3658	379	1912	Rheumatoid arthritis
0	0	0	0	0	Osteoarthritis
Unintentional injuries					
2847	7130	26 123	611	20 444	Road injury
42	286	1339	19	1078	Poisonings
1078	2891	8709	254	5229	Falls
220	1710	4681	39	598	Fire, heat and hot substances
447	2462	6325	140	3701	Drownings
240	1384	2599	56	2444	Exposure to mechanical forces
1020	3014	7442	179	2549	Other unintentional injuries

Table A3. DALYs attributable to occupation, by region, 2015

	Africa ¹	Americas		Eastern Mediterranean	
		HIC	LMIC	HIC	LMIC
Population	993 162 813	379 204 188	603 571 688	52 700 445	603 491 438
Total deaths	629 603 276	108 575 810	167 254 597	9 981 142	237 091 647
Total occupational deaths	13 756 364	2 637 212	5 545 959	295 889	3 662 391
Burden attributable to occupation	2.2%	2.4%	3.3%	3.0%	1.5%
Infectious diseases					
HIV/AIDS	4 803 513	1131	81 674	91	12 777
Sexually transmitted diseases²	137 840	9545	10 235	7405	31 026
Hepatitis B	23 808	3	1629	0	3721
Hepatitis C	134	9	29	1	33
Noncommunicable diseases					
Cancers					
Trachea, bronchus and lung cancer	152 130	598 988	546 171	20 028	256 053
Mesothelioma	7999	52 226	11 390	348	5850
Larynx cancer	11 548	5325	38 173	639	17 890
Nasopharynx cancer	2389	70	435	116	1216
Kidney cancer	220	230	970	49	353
Ovarian cancer	2849	1521	2997	30	1402
Leukaemia	21 725	5008	27 327	1601	18 290
Hearing loss	742 424	69 179	473 525	24 086	356 262
COPD	545 923	216 532	372 801	11 550	377 282
Asthma	634 164	53 003	146 155	8557	180 469
Other respiratory diseases³	14 903	9479	15 251	1229	46 466
Mental, behavioural and neurological disorders					
Depression	799 988	380 626	567 220	50 351	453 034
Drug and alcohol use	196 725	158 034	232 296	4094	51 332
Musculoskeletal diseases					
Low back and neck pain	1 190 525	299 700	652 571	44 183	668 687
Rheumatoid arthritis	71 249	126 090	114 861	3824	46 016
Osteoarthritis	152 496	154 835	201 527	15 790	160 540
Unintentional injuries					
Road injury	1 811 610	251 679	1 189 673	57 345	418 483
Poisonings	107 810	4794	10 598	246	17 726
Falls	456 429	107 565	237 055	15 476	94 150
Fire, heat and hot substances	337 035	21 209	55 096	3891	56 461
Drownings	320 077	18 733	134 268	3453	99 731
Exposure to mechanical forces	377 692	26 349	100 076	7288	63 600
Other unintentional injuries	833 158	65 351	321 955	14 218	223 542

Notes: HIC: high-income countries; LMIC: low- and middle-income countries; ¹ contains Seychelles; ² excludes HIV/AIDS; ³ includes pneumoconiosis.

Europe		South-East Asia	Western Pacific		
HIC	LMIC		HIC	LMIC	
502 352 344	410 632 000	1 926 539 250	212 935 516	1 658 379 125	Population
137 965 842	159 510 101	718 432 159	56 963 418	442 917 407	Total deaths
4 057 909	4 238 930	19 406 534	1 381 420	18 118 051	Total occupational deaths
2.9%	2.7%	2.7%	2.4%	4.1%	Burden attributable to occupation
					Infectious diseases
1296	15 526	159 696	138	53 490	HIV/AIDS
10 050	18 998	62 610	4360	33 289	Sexually transmitted diseases²
36	1024	37 934	5	6630	Hepatitis B
11	10	231	7	57	Hepatitis C
					Noncommunicable diseases
					Cancers
1 190 822	590 940	1 246 077	376 847	5 134 218	Trachea, bronchus and lung cancer
164 521	34 090	5182	37 894	42 697	Mesothelioma
14 685	16 115	63 160	2679	53 597	Larynx cancer
118	413	7001	584	20 151	Nasopharynx cancer
288	412	745	127	2303	Kidney cancer
5033	3106	3025	700	6261	Ovarian cancer
5044	8076	45 787	3031	97 655	Leukaemia
93 519	220 206	2 399 220	58 033	1 658 044	Hearing loss
129 927	247 309	4 344 835	107 034	2 636 050	COPD
77 146	69 991	1 028 793	29 706	415 332	Asthma
37 302	19 001	260 285	68 546	105 254	Other respiratory diseases³
					Mental, behavioural and neurological disorders
419 024	367 231	1 562 157	147 283	1 146 613	Depression
214 558	396 441	378 283	34 996	401 480	Drug and alcohol use
					Musculoskeletal diseases
583 906	589 130	3 172 105	229 363	2 771 608	Low back and neck pain
116 992	69 710	234 583	67 537	274 332	Rheumatoid arthritis
243 826	222 414	526 300	98 654	781 702	Osteoarthritis
					Unintentional injuries
256 057	460 249	1 534 939	42 465	1 287 469	Road injury
3308	19 037	82 803	1220	60 293	Poisonings
251 664	271 934	674 851	36 534	471 015	Falls
22 261	114 599	378 742	3721	51 893	Fire, heat and hot substances
23 060	133 795	362 652	6780	205 942	Drownings
50 543	115 020	237 334	6202	168 364	Exposure to mechanical forces
142 914	234 155	597 202	16975	232 313	Other unintentional injuries

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This comprehensive global assessment provides insights on the health impacts that could be avoided through healthier and safer workplaces. It is estimated that 2.1% of all deaths and 2.7% of the disease burden worldwide can be attributed to quantified occupational risks. These and the effects from many more unquantified risks are outlined.

Noncommunicable diseases contribute 70% to the total disease burden from occupational risks, with chronic pulmonary disease and cancers causing the highest work-related death toll, joined by back and neck pain when considering disease burden. Workers in low- and middle-income countries bear the largest share of deaths and disability from workplace exposures.

The report also clearly identifies that prevention strategies are available to avoid a significant percentage of work-related deaths and of the disease burden. Implementing such strategies is important in efforts to attain the Sustainable Development Goals. Targeted action towards healthier and safer workplaces will contribute to sustainably improving and protecting the lives of millions around the world.



PREVENTING DISEASE THROUGH
A HEALTHIER AND SAFER
WORKPLACE

CONTACT

DEPARTMENT OF PUBLIC HEALTH, ENVIRONMENTAL
AND SOCIAL DETERMINANTS OF HEALTH
WORLD HEALTH ORGANIZATION
AVENUE APPIA 20
1211 GENEVA 27
SWITZERLAND
<http://www.who.int/phe>

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