

**M**ore than 100 experts participated in the survey and provided a total of about 200 quantitative replies (some experts provided environmental attributable fractions for several diseases or injuries). Other estimates of the environmental attributable fraction came from the CRA (WHO, 2002). We report the results for each disease or disease group in the following sections.

## RESPIRATORY INFECTIONS

Indoor and outdoor air quality are two of the main environmental factors of concern for acute lower respiratory infections. Contributing risk factors include tobacco smoke, solid fuel use (Kirkwood et al., 1995; Smith et al., 2000), housing conditions and possibly hygiene. Previous estimates (WHO, 2002; Smith, Mehta and Maeusezahl-Feuz, 2004) showed that 36% of lower respiratory infections worldwide were attributable to solid fuel use alone, and 1% of all respiratory infections to outdoor air pollution (WHO, 2002; Cohen et al., 2004). In developed countries, solid fuel use was not significant, and environmental tobacco smoke may play a proportionally more important role in these countries. A study in Italy, for example, estimated that 21% of acute respiratory infections in the first two years of life were due to parental smoking (Forastiere et al., 2002).

A study in Europe determined that acute lower respiratory tract infections – attributable to indoor air pollution from solid fuel use alone – account for 4.6% of all deaths and 3.1% of all DALYs in children aged 0–4 (Valent et al., 2004).

Adding the effects of indoor and outdoor air pollution and other indoor conditions, at least 42% (95% Confidence Interval: 32–47%) of all lower respiratory infections were estimated to be attributable to the environment in developing countries. In developed countries, this rate was about halved to 20% (15–25%). It was more difficult to quantify the influence of other environmental factors (e.g. chilling, crowding), and the co-morbidities with other diseases that are partly attributable to the environment (e.g. malaria and diarrhoea), but they may add to the environmental health burden of lower respiratory infections.

The relationship of upper respiratory infections and otitis with environmental conditions was less well documented. In developing countries, about 24% (6–45%) of upper respiratory infections and otitis were attributable to environmental risk factors, such as outdoor and indoor air pollution, environmental tobacco smoke (Etzel et al., 1992; Stenstrom, Bernard and Ben-Simhon, 1993; California Environmental Protection Agency, 1997) and housing conditions. As with lower respiratory infections, the rate for upper respiratory infections and otitis was estimated to be lower in developed countries, at 12% (5–18%). Globally, more than 1.5 million deaths annually from respiratory infections are attributable to the environment (see Table A2.3).

**Globally more than 1.5 million deaths annually from respiratory infections are attributable to the environment, including at least 42% of lower respiratory infections and 24% of upper respiratory infections in developing countries.**



Cooking and heating with solid fuels over an open fire in Latin America. Many women and children in developing countries are thus exposed to very high concentrations of indoor air pollution, a major risk factor for respiratory infections.

Credit: Nigel Bruce/University of Liverpool

Globally, about 1.5 million deaths per year from diarrhoeal diseases are attributable to environmental factors, essentially water, sanitation and hygiene.



For a large part of the year, these settlements in Asia are surrounded by stagnant water. With no access to safe drinking water or basic sanitation, these children are constantly exposed to the risks of diarrhoea as well as other water-borne diseases.

Credit: Mark Edwards/Still Pictures

## DIARRHOEA

A large proportion of diarrhoeal diseases is caused by faecal-oral pathogens. In the case of infectious diarrhoea, transmission routes are affected by interactions between physical infrastructure and human behaviours. If sanitation or related hygiene is poor, e.g. when hand washing facilities are inadequate, or when faeces are disposed of improperly, human excreta may contaminate hands, which can then contaminate food or other humans (person-to-person transmission). Faecal pathogens are frequently transferred to the waterborne sewage system through flush toilets or latrines, and these may subsequently contaminate surface waters and groundwater. Human excreta also can directly contaminate the soil and enter into contact with people; flies may carry pathogens from excreta to food, for example. Through these pathways, drinking-water, recreational water or food may be contaminated and cause diarrhoeal disease following ingestion. Animal excreta also transmit pathogens. The predominant route will depend upon the survival characteristics of the pathogen, as well as local infrastructure and human behaviour. Many interventions have proven efficient in interrupting the pathogen transmission cycle at various points.

WHO recently estimated that 88% of all cases of diarrhoea globally were attributable to water, sanitation and hygiene (WHO, 2002; Prüss-Üstün et al., 2004a). The risk factor was defined as "drinking-water, sanitation and hygiene behaviour", as well as aspects of food safety that are related to water, sanitation and hygiene (i.e. food contamination by unsafe water, or the lack of domestic hygiene). Very little disease was transmitted through pathways other than those associated with water, sanitation and hygiene, or food (e.g. airborne transmission), and about 94% (84–98%) of all cases of diarrhoea around the world were attributable to the environment, resulting in more than 1.5 million deaths annually, mainly in children. The estimate for developed countries (90%; 75–98%) was slightly smaller because there were fewer cases of infectious diarrhoea, although non-infectious diarrhoea formed a relatively higher proportion of all diarrhoea cases. Water, sanitation and hygiene also play an important role in malnutrition (covered in the subsection, Malnutrition). Diarrhoea, attributable to water and sanitation accounted for 5.3% of deaths and 3.5% of DALY's in European children aged 0-14 (Valent et al., 2004).

## MALARIA

In humans, malaria is a disease caused by one of four parasite species belonging to the genus *Plasmodium*. The parasite is transmitted by the bite of an infected female mosquito of the genus *Anopheles*. The larval stages of *Anopheles* 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).

There are three main approaches to the environmental management of malaria:

- *Modify the environment.* This approach aims to permanently change land, water or vegetation conditions, so as to reduce vector habitats.
- *Manipulate the environment.* This approach temporarily produces unfavourable conditions for vector propagation and therefore needs to be repeated.
- *Modify or manipulate human habitation or behaviour.* This approach aims to reduce contact between humans and vectors (WHO, 1982).

At the time these definitions were formulated, the third approach included the use of mosquito nets. The successful introduction of insecticide-treated mosquito nets has put them in a category of their own, and blurred the boundary between environmental management and chemical control. For the current survey, the use of mosquito netting was not considered to be environmental management.

An array of environmental modification and manipulation methods are available for vector control in general, and malaria control in particular (WHO, 1982). Important features of environmental management strategies are their non-toxicity, relative ease of application, cost-effectiveness and sustainability (Bos and Mills, 1987; Ault, 1994; Utzinger, Tozan and Singer, 2001). Strategies for malaria can be grouped into at least three distinct eco-epidemiological settings:

- malaria of deep forests and hills, including forest fringe malaria;
- rural malaria attributable to water resource development and management (e.g. irrigation and large dams), wetlands, rivers, streams and coasts;
- urban and periurban malaria.

The modification or manipulation of human habitation to reduce human contact with vectors can be used relatively easily in all eco-epidemiological settings except for forest areas, where such efforts are less feasible and therefore generally not recommended.

Environmental modification steps to control malaria include:

- drainage
- levelling land
- filling depressions, borrow pits, pools and ponds
- contouring reservoirs
- modifying river boundaries
- lining canals to prevent seepage
- constructing hydraulic structures, such as weirs, to avoid stagnant water.

**Environmental management of malaria can involve modification or manipulation of the environment, as well as of human habitation and behaviour.**



*Anopheles stephensi*, the urban vector of malaria in south Asia takes a blood meal. Different mosquito species transmitting a number of diseases breed in man-made environments. This makes environmental management an important component of vector control.

Credit: CDC/Jim Gathany

An estimated 42% of the global malaria burden, or half a million deaths annually, could be prevented by environmental management.



A health worker informs residents of an Ethiopian community about the value of environmental management in preventing malaria infection, with the aid of a health education poster.

Credit: WHO/TDR/Olivier Martel

In an urban environment, environmental modification options also include building drains and storm-drains, modifying house design (including gutters and roof drains), and installing wastewater management facilities. Other environmental tools for controlling malaria include water management (e.g. intermittent, or alternate wet and dry irrigation; sprinkler, drip or central pivot irrigation); vegetation management in rural settings; safe practices for storing domestic water; management of solid waste in and around urban environments; and the maintenance of water supply and sanitation in urban areas.

It was estimated that 42% (30–53%) of the global malaria burden, or half a million deaths annually, could be prevented by environmental management, although the fraction amenable to environmental management varied slightly, depending on the region: 36% (25–47%) in the Eastern Mediterranean Region; 40% (34–46%) in the Western Pacific Region; 42% (28–55%) in sub-Saharan Africa; 42% (30–54%) in the South-East Asia Region; 50% (38–63%) in the European Region; and 64% (51–77%) in the Region of the Americas. The potential of environmental management to reduce the disease burden of malaria differed according to the type of environment (i.e. deep forests and hills, rural settings, and urban and periurban settings). The differences can be explained by local differences in the behaviour of *Anopheles* species (e.g. biting and resting behaviour), and by the number and characteristics of their breeding sites (e.g. in urban areas there are generally fewer breeding sites and they are easier to get to for vector control).

## INTESTINAL NEMATODE INFECTIONS

Ascariasis, trichuriasis and hookworm disease are all transmitted via soil and other media that are contaminated with excreta containing infective eggs or larvae. Transmission may take place near the home, or in a communal area with inadequate sanitation facilities and that is polluted with faeces. Transmission occurs when infective eggs are ingested, and in the case of hookworm disease, also when infective larvae penetrate the skin (Benenson, 1995). In addition, eggs may be found on uncooked food products contaminated with soil, faeces or wastewater. Transmission does not occur from person-to-person or from fresh faeces. Even if freshly excreted faeces are contaminated, it takes time for the parasite to develop and for the faeces to become infectious. These nematode infections can therefore be considered essentially 100% attributable to the environment, and they occur because of a lack of excreta management and inadequate hygiene practices (Prüss-Üstün et al., 2004a).

## TRACHOMA

Trachoma is a chronic contagious eye disease that can result in blindness. It is caused by *Chlamydia trachomatis*, and all transmission routes are hygiene related (e.g. direct infection by flies, person-to-person contact from clothing used to wipe children's faces, etc.). Risk factors for the disease include lack of facial cleanliness, poor access to water supplies, lack of latrines, and a high number of flies (Benenson, 1995; Prüss-Üstün et al., 2004a). Trachoma-transmitting flies can be controlled by managing excreta and by making improvements to houses. Several environmental control measures are effective (Sutter and Ballard, 1983; Esrey et al., 1991; Emerson et al., 1999, 2000; Prüss and Mariotti, 2000), and trachoma can be considered to be almost 100% attributable to the environment.

## SCHISTOSOMIASIS

*Schistosomiasis* is caused by infection with trematodes of the *Schistosoma* species. Most intermediate hosts of human *Schistosoma* parasites belong to three genera of snails; *Biomphalaria* and *Bulinus* are aquatic and *Oncomelaria* is amphibious. Transmission occurs through human contact with water containing free-swimming larval forms, penetrating skin. Water is contaminated by infected humans excreting schistosome eggs in faeces or urine (Benenson, 1995). Current understanding of disease transmission indicates that disease burden is fully attributable to risk factors associated with water, sanitation and hygiene (Prüss-Üstün et al., 2004a).

## CHAGAS DISEASE

Chagas disease (American trypanosomiasis) is caused by infection with the parasite *Trypanosoma cruzi*. The parasite is transmitted by various species of Mexican, and Central and South American triatomine bugs (Carcavallo et al., 1997; Coura et al., 2002), which have a range of resting and breeding places in and around houses. The disease can be controlled by interrupting transmission of the parasite. In the absence of effective drugs, an integrated vector management approach provides the best prevention and control option. Chagas disease burden can be reduced considerably by improving housing and by environmental management in peridomestic areas (Bos, 1990; Rozendaal, 1997; Rojas-De-Arias, 2001; Ramsey et al., 2003). Examples include structural improvements to houses (some triatomine bugs, e.g. *Triatoma infestans*, live in wall cracks), replacing palm-leaf roofs where *Rhodnius prolixus* is the vector, and cleaning or clearing wood stacks, goat corrals and chicken dens where *Triatoma dimidiata* tends to propagate. The global mean attributable fraction for Chagas disease was estimated to be 56% (31–80%) for environmental conditions that can be managed or manipulated.

Ascariasis, trichuriasis, hookworm disease, trachoma, schistosomiasis and Chagas disease could largely be prevented through improved hygiene, water and sanitation, and housing.



*Rhodnius prolixus*, here seen feeding on blood meals in a research setting, is among several species of triatomine bugs that transmit Chagas disease in central and south America. Housing improvement and peri-domestic environmental management are critical to sustained disease control.

Credit: Mark Edwards/Still Pictures

The disease burden of lymphatic filariasis, onchocerciasis and leishmaniasis could be reduced by improved water resource and waste management, and improved housing.



Children playing in a drain in an east African city are at an increased risk of water-associated diseases.

Credit: Ernst Tobisch/Still Pictures

## LYMPHATIC FILARIASIS

This disease is caused by worms that live in the lymphatic system and whose larvae are transmitted by the bite of an infected mosquito. There are a number of distinct transmission pathways for this infection, which are linked to the ecological requirements of different vectors in different locations (Rozendaal, 1997; R. Bos, personal communication). In urban settings of south and south-east Asia and in the Americas, the predominant parasitic worm (*Wuchereria bancrofti*) is linked to organically polluted water (open sewage drains and waste-water treatment ponds) where *Culex quinquefasciatus* breeds (Meyrowitsch et al., 1998; Erlanger et al., 2005). In Africa, both *Culex* and *Anopheles gambiae* are key vectors in coastal areas, whereas inland *A. gambiae* complex and *A. funestus* are the main vectors. As a result, lymphatic filariasis is linked to fresh-water collections and irrigation schemes (Appawu et al., 2001; Erlanger et al., 2005). In parts of the Western Pacific region, filariasis is transmitted by *Aedes* species, including *A. polynesiensis* which breeds in crab holes. The less important *Brugia malayi* parasite, endemic mainly in India and Sri Lanka, is transmitted by mosquitoes belonging to the genus *Mansonia*, which propagate in the presence of aquatic weeds.

The variety of locations and vectors involved in this disease was reflected in the large differences in estimates for the environmental attributable fraction for the disease. In the South-East Asia Region and Western Pacific Region the attributable fraction was estimated to be 82% (50–98%), while in the Region of the Americas it was 70% (60–80%), derived mainly from considering urban environmental management. In the Africa Region, the attributable fraction was 40% (20–68%), and the resulting global average was 66% (35–86%).

## ONCHOCERCIASIS

Onchocerciasis is caused by the pathogen, *Onchocerca volvulus*, which is transmitted by vectors (blackfly species belonging to the *Simulium damnosum* complex) that breed in rapidly flowing streams (Rozendaal, 1997; R. Bos, personal communication). In this analysis, only those breeding places in areas influenced by water resource projects were considered, particularly dams (e.g. building dams with a double-spillway design). Natural waters, which have limited opportunities for environmental management, were not considered. In this context, insecticide spraying of streams and rivers was not considered to be an environmental health action. Evidence suggests that disease transmission can be increased by forest degradation related to human activity, as deforested areas provide a favourable habitat for the vector of the more severe strain of the pathogen (Wilson et al., 2002; Adjami et al., 2004). The global environmental attributable fraction for this disease was estimated to be 10% (7–13%).

## LEISHMANIASIS

Leishmaniasis is caused by parasitic protozoan species belonging to the genus *Leishmania*, which are transmitted by sandflies. Clinical manifestations are species-related, ranging from visceral to cutaneous to mucocutaneous. To some extent, leishmaniasis could be prevented in Africa and Asia by making improvements to housing. Houses with cracks in mud or masonry walls, as well as compounds where cattle are kept in close proximity to living quarters, provide breeding sites for the flies (Rozendaal, 1997; Desjeux, 2001; Bucheton et al., 2002; Moreira, 2003; R. Bos, personal communication). In these regions, the disease fraction attributable to the environment was estimated to be 27% (11–40%). In Central and South America, the vectors breed mainly in natural environments (e.g. forests), but increasingly transmission to humans occurs in and around houses (Campbell-Lendrum et al., 2001; Yadon et al., 2003). Interventions can be effective, such as those that improve housing. The global environmental attributable fraction for this disease was estimated to be 12% (1–30%).

## DENGUE

Dengue and dengue haemorrhagic fever could be almost entirely prevented by good management of water bodies in and around houses, which are breeding sites for the main mosquito vector, *Aedes aegypti*. This species commonly breeds in temporary water-storage containers in the domestic (and sometimes the natural) environment, such as tanks and drums, plant pots, and also in standing water in solid waste, including tyres and discarded food containers. *Aedes albopictus* is an important secondary vector in some areas of the Western Pacific and South-East Asia Regions, while *Aedes polynesiensis*, which breeds in crab holes, transmits dengue on a number of Pacific islands. In such circumstances, the problem of dengue cannot be resolved simply by reducing or effectively managing *Aedes aegypti* breeding sites (Rozendaal, 1997; Heukelbach et al., 2001; R. Bos, personal communication). The global mean environmental attributable fraction for dengue was estimated to be 95% (90–99%).

## JAPANESE ENCEPHALITIS

Vectors involved in the transmission of Japanese encephalitis include *Culex tritaeniorhynchus* and species belonging to the *C. gelindus* complex. This vector-borne disease could be efficiently prevented by environmental management, largely by managing irrigation areas (mainly rice fields) and their access to farm animals, pigs in particular (Rozendaal, 1997; Keiser et al., 2005; Bos, personal communication). The disease is therefore almost completely associated with the environment, with an estimated attributable fraction of 95% (90–99%).

Dengue and dengue haemorrhagic fevers could be almost entirely prevented by good management of water containers in and around houses.



Standing water in a Latin American town provides a potential breeding ground for the mosquito vectors of diseases associated with poor solid waste management.

Credit: WHO/TDR/Mark Edwards

**Commercial sex workers and migrant workers are at increased risk of acquiring or transmitting the human immunodeficiency virus (HIV).**



Prostitutes in Brazil have formed an association to educate themselves about AIDS.

Credit: Mark Edwards/Still Pictures

## HIV/AIDS

Certain occupational groups are at increased risk of acquiring or transmitting the human immunodeficiency virus (HIV), which causes acquired immunodeficiency syndrome (AIDS). These include commercial sex workers, health-care workers who may be infected by sharps injuries or other exposures, and workers who spend part of the year away from their families (referred to as workers at "intermediate risk"). Workers at intermediate risk mainly include the uniformed workforce (e.g. policemen, the military), miners and truck drivers. Because they live away from their families part of the year, they are more likely to have sex with sex workers, and thus be at increased risk (Evian et al., 2004; UNAIDS/WHO, 2004; US Census Bureau and UNAIDS, 2004). Commercial sex workers may be at high risk, however they comprise a relatively small percentage of the general population. For example, commercial sex workers typically represent 0.4–1% of the general population in most regions, and 1–4% in sub-Saharan Africa and the industrializing part of the Western Pacific Region. The intermediate risk group is larger, generally 3% or more of the total population, but their risk is 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 in commercial sex workers (UNAIDS/WHO, 2004), or workers at intermediate risk (after accounting for competing risks, such as intravenous drug use). In adults, for example, the prevalence of HIV in commercial sex workers may be 2–20 times higher than in the general population, depending on the region. Only about 0.02% of the global HIV/AIDS burden is estimated to be caused by percutaneous injuries to health-care workers (Prüss-Üstün, Rapiti and Hutin, 2003).

The occupational-related attributable fraction for HIV/AIDS in adults was estimated to be 4–8% (2–13%) in most regions; it was lower in the developed part of the Western Pacific Region, at 2–3% (1–5%). In regions such as sub-Saharan Africa and the South-East Asia Region – which have higher rates of sex workers or very high rates of HIV in commercial sex workers as compared to the general population – the attributable fraction was estimated to be as high as 9–15% (4–20%). Globally, occupational causes accounted for about 9% (5–14%) of HIV transmissions, causing 250,000 deaths annually. This estimate only covers HIV transmission to workers, 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. The impact of prevention that is targeted to certain occupational groups may therefore be more far reaching than simply improving workers' health (the parameter used in this study to simplify quantification).

## SEXUALLY TRANSMITTED DISEASES

The sexually transmitted diseases (STDs) considered in this section include only the main bacterial infections, syphilis, chlamydia and gonorrhoea. Viral infections are not covered, although human papilloma virus (HPV) infections are partly captured in the section on cancers, as they are linked to cervical and uterine cancer. Hepatitis B, hepatitis C and HIV/AIDS are covered in separate sections.

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 (Riedner et al., 2003; Sugihantono et al., 2003; Xueref et al., 2003; Nessa et al., 2005), because disease can be transmitted during occupational activity. Another group of workers, including mainly the uniformed workforce and migrant workers (mainly truck drivers, policemen, military, sailors, miners, certain construction workers), are also at increased risk of infection because their work takes them away from home for extended periods and they are more likely to seek partners, particularly among commercial sex workers (Anonymous, 1994; Gawande et al., 2000). 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 0.4–4% for sex workers, depending on the country), and only about 3% or more of all workers are at increased risk. The total attributable fraction for the occupational disease burden of the main bacterial STDs (syphilis, chlamydia and gonorrhoea) was estimated to be 7–9% (4–12%) for most regions, and about 20% (15–25%) for regions with high rates of sex workers, such as sub-Saharan Africa and the industrializing part of the Western Pacific Region. The global average for the attributable fraction of occupational STDs was about 17% (15–19%).

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, but it is not considered here.

## HEPATITIS B AND HEPATITIS C

Hepatitis B and hepatitis C have an occupational component, as certain occupational groups are at increased risk of infection with the hepatitis B virus (HBV) or hepatitis 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, workers exposed to percutaneous injuries with contaminated sharp objects (e.g. nurses, doctors), and workers at

Each year, 16 400 hepatitis C and 65 600 hepatitis B infections occur in health workers as a result of injuries by contaminated sharp objects.



Intensive care nurse prepares for a procedure in a provincial hospital in Viet Nam.

Credit: Susan Wilburn

Crowding, and certain home or workplace exposures to air pollutants, are environmental factors that increase the burden of disease from tuberculosis.



A chest exam for tuberculosis.

Credit: WHO/TBP/Davenport

intermediate risk (e.g. migrant workers, members of the uniformed workforce, miners, truck drivers and sailors) who spend time away from home and are more likely to seek out the services of sex workers.

Although HBV is highly sexually transmissible, it is not always possible to dissociate this route of transmission from other means, as studies of commercial sex workers have shown. Nevertheless, hepatitis B is generally more prevalent in commercial sex workers than in the general population, for countries in which HBV prevalence is low or intermediate (Ishi et al., 2001; Camejo, Mata and Diaz, 2003; Mak et al., 2003; P. Van Damme, personal communication). Sexual transmission of HCV between monogamous partners is likely to be low compared with other causes (Neumayr et al., 1999; Vandelli et al., 2004), but may account for as much as 10–20% of all HCV infections (Alter, 1997). Occupational transmission of HCV to sex workers has a low public-health priority and was not considered here.

It was estimated that the attributable fractions 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-Üstün, Rapiti and Hutin, 2003). The total attributable fraction for occupational HBV infections in adults was estimated to be 3% (1–4%) in regions with low or intermediate hepatitis B prevalence (i.e. most regions, besides sub-Saharan Africa, China, parts of south-east Asia and selected countries). In high-prevalence regions, only infections of health-care workers from sharps injuries were considered.

## TUBERCULOSIS

The risk of infection by *Mycobacterium tuberculosis* and progression to disease depends not only on the human host, but on a range of environmental factors. For instance, crowding in households or other settings, may favour casual transmission of the causal pathogen, increasing the likelihood of prolonged close contact between susceptible people and infectious tuberculosis cases (Antunes and Waldman, 2001; Lienhardt, 2001; Clark, Riben and Nowgesic, 2002). Malnutrition increases the risk of progression to tuberculosis, and worsens the prognosis, because it compromises the immune system (Byrd, Mehta and Roy, 2002; Zachariah et al., 2002). Exposure to indoor smoke from solid fuels (Mishra, Retherford and Smith, 1999; Desai, Mehta and Smith, 2004) and environmental tobacco smoke both have been associated with increased tuberculosis rates, but how they are associated is not well understood.

Certain occupational groups are at increased risk of tuberculosis, particularly miners exposed to airborne particles such as silica or coal dust (Trapido et al., 1998; Williams et al., 1998; Corbett et al., 1999, 2000; Davies et al., 2001; Rom and Garay, 2003), and workers handling asbestos (Segarra-Obiol, Lopez-Ibanez and Perez Nicolas, 1983). Health-care workers who come into contact with tuberculosis patients are at increased risk of infection (Takeda, Robazzi and Lavrador, 2001; Anonymous, 2004; Jelip et al., 2004). In some settings, such as hospitals and prisons, tuberculosis rates are particularly high (Braun et al., 1987; Eyob et al., 2002).

For most of the world, it was estimated that about 19% (6–41%) of the total tuberculosis burden was attributable to the environment, although in areas where the HIV epidemic had a large impact on tuberculosis incidence it was likely that environmental factors had a smaller effect. In parts of Africa that are strongly affected by HIV/AIDS, for example, the attributable fraction for tuberculosis associated with the environment was estimated to be only 14% (6–24%). Although tuberculosis may have a strong environmental component, this does not mean that the best way to control the epidemic is through environmental management. It is clear, however, that managing environmental risk factors could significantly reduce the disease burden of tuberculosis.

### PERINATAL CONDITIONS

For the purpose of this study, perinatal conditions principally include low birth weight, prematurity, birth asphyxia and birth trauma. This definition is relatively narrow as it excludes stillbirths, malformations and other conditions affecting liveborn infants that may be affected by environmental factors.

Higher rates of low-birth-weight infants were observed for mothers exposed to the environmental risks of air pollution, tobacco smoke or various chemicals (Ritz and Yu, 1999; Seidler et al., 1999; Chen and Omaye, 2001; Boy, Bruce and Delgado, 2002; Desai, Mehta and Smith, 2004; Maisonet et al., 2004). In Italy, for example, it was estimated that environmental tobacco smoke alone accounted for 7.9% of all low birth weights (Forastiere et al., 2002). In developing countries, exposures to environmental hazards such as: unsafe water and inadequate sanitation; unsafe nutrition (itself related to poor water and sanitation); or maternal exposure to pesticides or other chemicals, constitute important risks to infant health, increasing the mortality rate for low-birth-weight and preterm infants (Zhang, Cai and Lee, 1992; Taha and Gray, 1993; Longnecker et al., 2001). Birth asphyxia and trauma could be caused by a low maternal Body Mass Index, however the contribution of these risk factors to the overall infant mortality rate is probably low.

Infants of mothers exposed to air pollution, environmental tobacco smoke and other chemicals had higher rates of low birth weight.



Active and passive smoking during coffee break in an office in Europe.

Credit: Mike Schroeder/Still Pictures

**Malnutrition probably plays a role in more than half of all child deaths; 50% of malnutrition's disease burden is attributable to the environment.**



Measuring head circumference as part of a survey into children's health and nutrition in India.

Credit: Mark Edwards/Still Pictures

It was estimated that environmental causes accounted for 6% (2–10%) of all adverse perinatal conditions in developed countries, and for 11% (3–25%) in developing countries (where exposures to environmental risks were estimated to be higher). It should be noted that the relationship between environmental exposures and perinatal conditions is relatively poorly documented, particularly in developing countries.

### CONGENITAL ANOMALIES

Congenital anomalies include conditions such as abdominal wall effects, anencephalies, anorectal atresia, cleft lip or palate, oesophageal atresia, heart anomalies, spina bifida or Down's syndrome. Some have been linked to environmental or workplace exposures of pregnant women to chemicals or radioactivity, and to ambient air pollution (Reznik et al., 1992; Czeizel et al., 1993; Nurminen, 1995; Ritz et al., 2002). It was estimated that 5% (2–10%) of all congenital anomalies were attributable to environmental causes.

### MALNUTRITION

Malnutrition has been used to refer both to overnutrition and undernutrition, but in this analysis we use the term exclusively to refer to undernutrition, measured as poor anthropometric status. Individual nutritional status depends on the food that an individual eats, his or her general health, and the physical environment. In all three aspects, poor water and sanitation play an important role in malnutrition (WHO, 2005a), and several infectious diseases associated with malnutrition, including diarrhoea and other diseases caused by intestinal parasites, are related to poor water, sanitation, hygiene and food safety (Martorell, Mendoza and Castillo, 1988; WHO, 1995; Prüss-Üstün et al., 2004a). It has also been shown that the levels of water and sanitation services significantly affect Z-scores and weight gain in infants (Esrey, Habicht and Casella, 1992; Esrey, 1996; Checkley et al., 2004).

Malnutrition is also related to feeding habits (Motarjemi et al., 1993), while the influence of a genetic component on nutritional status may only be small (Habicht et al., 1974; WHO, 2000; Bhandari et al., 2004). Land degradation and soil pollution, as well as climate change, can also contribute to malnutrition to a certain extent. It was estimated that climate change accounted for 2% of the health burden of malnutrition (WHO, 2002). Overall, 50% (39–61%) of the health burden of malnutrition was estimated to be attributable to the environment, and in particular to poor water, sanitation and hygiene. Malnutrition causes vulnerability and increases the risk of adverse health outcomes, particularly in children.

Malnourished children tend to have more frequent episodes of severe diarrhoea and are more susceptible to infectious diseases, such as respiratory infections and meningitis. Malnourished children have a poorer prognosis for almost all infectious diseases (except HIV), and malnutrition is thought to play a role in more than half of all child deaths worldwide (Pelletier, 1994; Schroeder and Brown, 1994), which makes malnutrition one of the most important risk factors for children globally (Fishman et al., 2004). In this analysis, we included the infectious disease burden of malnutrition in children that is associated with the environment.

## CANCERS

Malignant neoplasms at several sites of the body have been associated with exposures to occupational and environmental risk factors. Although cancers from environmental causes cannot be distinguished from cancers from other causes, as for many other diseases, the contributions of environmental causes have been highlighted by analysing differences in cancer incidences by geography and over time, and by studying cancer rates in migrant populations (IARC, 1990). The effects of occupational carcinogens have been particularly well documented, with 28 agents considered to be definite, 27 agents probable, and 113 agents possible occupational carcinogens (Siemiatycki et al., 2004).

Lung cancer causes the largest disease burden of all cancers globally, or about 15% of the burden of all cancers. By far the largest risk factor for lung cancer is smoking, at 66% (WHO, 2002). About 9% of the disease burden of lung cancer has been attributed to occupation (WHO, 2002; Concha-Barrientos et al., 2004), about 5% to outdoor air pollution (WHO, 2002; Cohen et al., 2004) and 1% to exposure to indoor smoke from solid fuels (Smith, Corvalán and Maeusezahl-Feuz, 2004). Other exposures are also likely to pose a risk. These include exposure to environmental tobacco smoke (Taylor et al., 2001; IARC, 2004); radon (Lubin and Boice, 1997; Committee on Health Risks of Exposure to Radon, 1999; Pavia et al., 2003); and occupational exposure to ionizing radiation (IARC, 1992), asbestos, and other chemicals (e.g. chromium, nickel, cadmium).

Smoking may have an additive or multiplicative effect with some environmental exposures (Williams and Sandler, 2001). In Finland, for example, work-related factors accounted for 24% of lung cancer mortality in adults, but for only 8% of all cancer fatalities in adults (Nurminen and Karjalainen, 2001). It was estimated that environmental factors account for 31% of the global disease burden of lung cancer and 30% (6–55%) of the disease burden in developed countries, for both men and women. In developing countries, the attributable environmental fractions were 33% (6–65%) for men, and 25% (6–37%) for women.

**Smoking is the largest risk factor for lung cancer, but environmental causes also account for an estimated 31% of global lung cancer burden.**



A schoolgirl with a face mask for protection from smokestack pollution emissions of factories in her neighbourhood in the eastern Mediterranean region.

Credit: Munir NASA/UNEP/Still Pictures

Melanomas are linked to excessive UV exposure, yet we continue to deplete the ozone layer and fail to use personal protection.



Encouraging children in Australia to wear hats on the beach as part of the national SLIP SLAP SLOP campaign to increase awareness about health risks arising from excessive exposure to the sun's rays.

Credit: Mark Edwards/Still Pictures

The second most important neoplasm in terms of disease burden is stomach cancer, particularly in developing countries. Stomach cancer is associated with *Helicobacter pylori* infection, which is relatively common in developing countries, and transmission may be facilitated by poor sanitation and crowding. Other neoplasms, such as leukaemia, have been associated with chemical agents. For example, 2% of the leukaemia disease burden was attributed to occupational exposures to chemicals whose carcinogenic properties have been clearly established, such as benzene and ethylene oxide (WHO, 2002; Concha-Barrientos et al., 2004). There is also good evidence linking melanomas to excessive UV exposure – yet we continue to deplete the ozone layer, fail to use personal protection, and indulge in other risky behaviour leading to excessive UV exposure.

Other risk factors for cancer include aflatoxins in food (liver cancer), asbestos in drinking water (several cancers, including skin cancer), and human papilloma viruses (cervical cancer, can be occupationally transmitted to sex workers). Also, HIV-related Kaposi's sarcoma can be occupationally transmitted and is associated with lymphoma. Other environmental or occupational exposures have been associated with various neoplasms, but the quantitative evidence could not be established. In developed countries, it was estimated that 16% (10–34%) of cancers in men (other than lung cancers), and 13% (10–23%) in women, were attributable to the environment. In developing countries, the corresponding attributable fractions were 18% (10–45%) in men and 16% (10–35%) in women. The uncertainty surrounding these estimates is due to the fact that evidence linking specific environmental and occupational exposures to various cancers was incomplete. Globally, about 19% (12–29%) of all cancers were estimated to be attributable to the environment, resulting in 1.3 million deaths each year.

## NEUROPSYCHIATRIC DISORDERS

This large group of diseases includes disorders such as Alzheimer and other dementias, bipolar affective disorders, Parkinson disease, schizophrenia, epilepsy, alcohol use and drug use disorder, multiple sclerosis, insomnia, migraine, panic disorder, post-traumatic stress disorder, and lead-induced mild mental retardation. Of all the neuropsychiatric disorders, unipolar depressive disorder causes the largest disease burden. Many of these conditions have a small-to-moderate link to the environment or occupation. Depression has been linked to occupational stress (Tennant, 2001), insomnia to noise exposure (Passchier-Vermeer and Passchier, 2000; Franssen and Kwekkeboom, 2003) and, more recently, conditions such as Parkinson disease have been linked to exposure to chemicals (Huang, de la Fuente-Fernandez and Stroessl, 2003; Tan et al., 2004).

Parkinson disease also could be linked to occupational head trauma, as could epilepsy. Drug use and alcohol disorder have been linked to the occupational environment, such as coca growing, or working in the entertainment or alcohol industry (Wilhelm et al., 2004). Post-traumatic stress disorders have been linked to disasters such as floods, earthquakes and fires, which could be partly prevented by environmental measures. Dams and land-use patterns could be used to control flooding, for example, and materials could be used to build sturdier houses that could better weather the effects of fire or earthquake. Insomnia has an environmental and occupational component, mainly through exposure to noise, or occupational stress.

The loss of IQ points caused by exposure to lead in early childhood can lead to mild mental retardation, and this environmental contribution to the disease burden is captured in the neuropsychiatric group of disorders. It was estimated that about 800 000 children were affected by exposure to lead each year (WHO, 2002; Prüss-Ustün et al., 2004). Other disorders may be associated with population density in urban settings and poor quality of the local environment. In Finland, for example, it was estimated that 4% of mental disorders and 3% of nervous system diseases were linked to occupation (Nurminen and Karjalainen, 2001). Overall, the environmental contribution to the disease burden of neuropsychiatric disorders was relatively modest, and the attributable fraction was estimated to be only 13% (10–16%). The neuropsychiatric diseases with the largest environmental components included insomnia, migraine, post-traumatic stress disorder, epilepsy (in developing countries), and alcohol use disorder, with attributable fractions ranging between 10% and 20%. Those for depression, epilepsy (in developed countries) and Parkinson disease ranged from 5% to 10%, while other neuropsychiatric diseases contributed less than 5% of the environmental burden.

## CATARACTS

Cataracts have been associated with exposure to sunlight and environmental tobacco smoke (Hollows and Moran, 1981; Collman et al., 1988; Taylor et al., 1988; West, 1992; West et al., 1998; McCarthy, Nanjan and Taylor, 2000), as well as to smoke from solid household fuels (Mohan et al., 1989; Zodpey and Ughade, 1999; Desai, Mehta and Smith, 2004), and with dehydration from diarrhoea that is largely attributable to environmental causes (Minissian, Mehra and Jones, 1984; Minissian, Mehra and Verrey, 1989; Bhatnagar et al., 1991). However, more work is needed in these areas. Globally, about 5% of cortical cataracts have been associated with exposure to UV radiation (Lucas, 2004). In total, it was estimated that 7% (5–10%) of all cataracts are attributable to environmental risks.

**In the year 2000, about 800 000 children were affected by lead exposure, leading to lower IQ and potential mild mental retardation.**



A child directly exposed to tailpipe emissions from an automobile, which may heighten environmental exposure to lead in countries where leaded gasoline has not yet been phased out.

Credit: Harmut Schwarzbach/Still Pictures

Some 2.5 million people die every year from cardiovascular disease attributable to environmental factors, including work-related stress as well as chemical, air pollution, and environmental tobacco smoke exposures.



Processing fish in the USA. Workplace conditions, including the demands of assembly line work, can be a factor in stress.

Credit: Steven Kazlowski/Still Pictures

## DEAFNESS

Hearing loss leading to deafness can be caused by occupational exposure to high levels of noise. The attributable fraction for the disease burden of occupational deafness was estimated to be 16% of the global average disease burden for all causes of deafness (WHO, 2002; Concha-Barrientos et al., 2004).

## CARDIOVASCULAR DISEASES

Cardiovascular diseases have been associated with environmental risks such as air pollution, (Pope et al., 2002), risks in the workplace, exposure to chemicals such as lead (Schwartz, 1995) and exposure to environmental tobacco smoke (Kaur et al., 2004). Lead exposure, for example, can increase blood pressure, which in turn increases the risk of cardiovascular disease. Lead exposure was estimated to account for 2% of the ischaemic heart disease burden and 3% of the cerebrovascular disease burden (WHO, 2002; Prüss-Üstün et al., 2004).

Exposures to outdoor air pollution accounted for approximately 2% of the global cardiopulmonary disease burden (WHO, 2002; Cohen et al., 2004). Several other risk factors, such as low mineral content in drinking-water, are suspected of being associated with cardiovascular diseases, but evidence is still being developed and debated (WHO, 2006a).

Other environmental risks can be generated by stressful conditions in the workplace and ischaemic heart disease has been linked to stress at work (Bosma et al., 1988; WHO, 2002). Stressful workplace conditions include an imbalance in the effort-reward mix, long work hours, shiftwork, psychosocial stressors and physical exertion (Karasek et al., 1988; Johnson, Hall and Theorell, 1989; Belkic et al., 2004; Rosengren et al., 2004).

In Finland, it was estimated that occupational risks accounted for 17% of the deaths from ischaemic heart disease, and 11% of those from stroke (Nurminen and Karjalainen, 2001). In the USA, about 12% of the ischaemic heart disease burden was related to occupation, for the age group 20–69 years. This estimate was based on the specific risks of job control, noise, shift work and environmental tobacco smoke at work (Steenland et al., 2003). In Denmark, it has been estimated that about 16% of the cardiovascular disease burden could be prevented in men with non-sedentary occupations, and 22% in women with non-sedentary occupations. These figures increased to 51% and 55%, respectively, if men and women with sedentary work were included in the analysis (Olsen and Kristensen, 1991). In total, 16% (7–23%) of the total burden of cardiovascular disease was attributed to the environment, corresponding to 2.5 million deaths per year.

## CHRONIC OBSTRUCTIVE PULMONARY DISEASE

Chronic obstructive pulmonary disease (COPD) is a slowly progressing disease characterized by a gradual loss of lung function. In terms of total disease burden, the most important risk factor is active smoking, estimated to contribute to 36% of the global disease burden of COPD (WHO, 2002). Most other risk factors are occupational or environmental, including dusts and chemicals in the workplace, air pollution, and environmental (second hand) tobacco smoke (National Heart, Lung and Blood Institute, 2005). Occupational exposures to airborne particulates, for example, were responsible for 12% of the global COPD disease burden (WHO, 2002; Concha-Barrientos et al., 2004), and exposures to indoor smoke from solid fuels accounted for a further 22% (WHO, 2002; Smith, Corvalán and Maeusezahl-Feuz, 2004). Outdoor air pollution accounted for 3% of cardiopulmonary mortality (Cohen et al., 2004).

Globally, it was estimated that 42% (37–47%) of the COPD disease burden could be attributed to the environment. This estimate was derived by combining CRA estimates (WHO, 2002), which did not include environmental risks such as environmental tobacco smoke, with those of the experts, which did account for the additional environmental risks (Baldacci and Viegi, 2002; Gauderman et al., 2004; Vineis et al., 2005). The CRA estimates (which covered 90% of the risks included in the expert survey results), were adjusted to cover additional environmental risks such as environmental tobacco smoke (second-hand smoke), using the expert opinion survey results, to give a final distribution for the estimated total disease burden from COPD.

The attributable fractions for COPD risk factors vary significantly between countries and by gender, a result of differences in the main risk factors to which people are exposed. In countries where solid fuel is widely used in homes for cooking or heating, indoor smoke levels can be high, and mean attributable fractions often exceeded 40%, with higher values for women than for men. In more developed regions, with little reliance on burning solid fuel in the home, mean attributable fractions were between 10% and 30%, with higher values for men because of occupational exposures to smoke.

## ASTHMA

Asthma development and exacerbation can be triggered by a variety of indoor and outdoor environmental exposures. Indoor exposures to dampness, dust mites and fungal allergens may account for 20% of asthma prevalence (Melse and de Hollander, 2001). Indoor smoke from solid fuels (Mohamed et al., 1995; Xu, Niu and Christian, 1996; Desai et al., 2004) and environmental tobacco smoke (Etzel, 2003; Tatum and Shapiro, 2005) are also significant triggers for asthma symptoms and attacks.

An estimated 42% of COPD is attributable to environmental risks; occupational exposures to airborne particulates were responsible for 12% of this global COPD disease burden.



Protecting worker health from environmental dust at a cement plant in Africa.

Credit: Jorden Schytte/Still Pictures

**Asthma can be triggered or exacerbated by indoor or outdoor exposures to dampness, dust mites, fungal allergens, environmental tobacco smoke and air pollution.**



Child using inhaler during an asthma attack (UK).

Credit: Mike Jackson/Still Pictures

Outdoor environmental exposures, such as to poor air quality (e.g. smog), are also known to exacerbate asthma (Koenig, 1999; Etzel, 2003). Occupational exposures alone accounted for about 11% of the total disease burden from asthma (WHO, 2002; Concha-Barrientos et al., 2004). Total environmental exposures were estimated to account for 44% (26–53%). The estimate for environment exposures did not include outdoor exposure to pollen, as this is not realistically modifiable.

## MUSCULOSKELETAL DISEASES

Musculoskeletal diseases included in this study were the main categories of rheumatoid arthritis, osteoarthritis, low back pain, gout, and a group of "other musculoskeletal diseases". Low back pain is associated with exposure to ergonomic stressors at work, and it has been estimated that occupational exposures accounted for 37% of the global burden of disease from low back pain (WHO, 2002; Concha-Barrientos, et al., 2004). The mean attributable fraction was generally higher for men than for women (41% versus 32%), because men were more frequently engaged in occupations that exposed them to risk.

Rheumatoid arthritis and osteoarthritis have both been linked to occupational risks, such as exposure to vibrations, repetitive trauma, knee bending or lifting heavy weights. The incidences of these diseases are higher in occupational groups such as farmers, truck drivers and unskilled workers (Maetzel et al., 1997; Lievense et al., 2001; Khuder, Peshimam and Agraharam, 2002; Kirkhorn, Greenlee and Reeser, 2003; Rossignol et al., 2003; Olsson et al., 2004; Yoshimura et al., 2004). It was estimated that environmental factors account for 17% (7–29%) of the disease burden from rheumatoid arthritis and 20% (13–26%) of that from osteoarthritis. The group of "other musculoskeletal diseases" includes other forms of arthritis, arthropaties, joint disorders, systemic connective tissue disorders, muscle and soft tissue disorders. Evidence indicates that these diseases are also linked to occupational conditions, and it was estimated that 15% (7–23%) of the disease burden for this group of musculoskeletal diseases was attributable to occupational risk factors.

## ROAD TRAFFIC INJURIES

The frequency of road traffic injuries can be influenced by environmental conditions related to land use policies and practices; inappropriate road design (road environment); urban structure and density (layout and hierarchy of road systems and residential areas); and poor matches of road design and vehicles. Other environmental issues include poor street lighting and signs, poor road maintenance and narrow roads (Qin et al., 2004). Traffic calming measures, such as one-way streets, road narrowing, speed

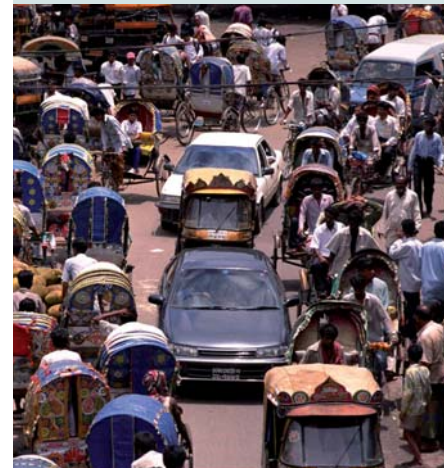
limits, street closures and speed bumps, may be effective in reducing injury (Forjuoh and Li, 1996; Elvik, 2001; Bunn et al., 2003; Mohan, 2004). Other successful measures include designating segregated bicycle lanes on urban roads, introducing barriers along the roadside, and pedestrian crossings (Forjuoh and Li, 1996; Peden et al., 2004; Racioppi et al., 2004).

The CRA study estimated that occupational factors contributed 6% of the global disease burden of road traffic injuries (WHO, 2002; Concha-Barrientos et al., 2004). It is relatively difficult to assess the contribution of environmental factors using intervention studies, because most such studies must be implemented within an existing built environment, with only minor constructional modifications possible. Also, longer-term environmental changes, such as modifications to the urban geography, density or road layout, or changes in the use of motor vehicles, could not be measured. Despite these limitations, it was estimated that 25% (12–59%) of road traffic injuries in Western Europe were attributable to the environment, 17% (5–50%) in Australia, North America and Japan, and 42% (26–60%) in developing countries. The global average for road accidents attributable to environmental factors was 40% (25–57%).

### UNINTENTIONAL POISONINGS

Unintentional poisonings analysed in this study were poisonings by chemicals or other noxious substances, including drugs, and toxic vapours or gases. Suicides and homicides, attempted or actual, as well as drug abuse, and other intentional poisonings were not included in this category. Food poisonings, or contact with venomous animals or plants, were analysed, but under a separate category ("other unintentional injuries"). Many unintentional poisonings could be avoided if toxic chemicals were handled and stored safely, and if users were educated about the dangers of products and medications (e.g. by providing them with clear information about using medications) (McGuigan, 1999). Nevertheless, some poisonings from accidental drug overuse or negligence still occur, even when chemical safety measures are implemented and adequate information/education provided. These poisonings were not considered to be related to occupation or environment. It was estimated that 68% (46–84%) of poisonings in adults were attributable to occupation or the environment, and 85% (60–98%) in children. The figure is greater for children because certain behavioural and developmental factors specific to this group also make them more vulnerable to environmental risks associated with poisonings. For adults and children combined, environmental risk factors accounted for an average of 71% (52–85%) of all unintentional poisonings.

Traffic calming measures and improved design for cyclists and pedestrians can help reduce road traffic injuries.



Motorized traffic weaves its way through crowds of pedestrians and three-wheelers in a busy Asian city.

Credit: WHO

Falls, risk of fire and other forms of unintentional injury could be reduced through improvements to housing, recreational and built environments, as well as workplace settings.



Construction worker in Argentina. Building site safety is an important factor in worker health in developed and developing countries.

Credit: Mark Edwards/Still Pictures

## FALLS

The number of falls could be reduced by improving the housing environment (e.g. by installing window guards or grab rails, removing slippery surfaces, and replacing lighting), by limiting access to building sites, and by improving the safety of recreational environments (Forjuoh and Li, 1996; Cryer, 2001; Gillespie et al., 2003; Millward, Morgan and Kelly, 2003; WHO Regional Office for Europe, 2004). In developed countries, about 26% (16–47%) of all falls were attributed to the environment. Although there were few data for developing countries, the corresponding figure was estimated to be 31% (17–60%). Approximately 12% of all falls worldwide occurred at work (WHO, 2002; Concha-Barrientos, 2004).

## FIRES

Risks for domestic fires include the types of materials used to build the house, and the types of home furnishings (e.g. tapestry, upholstery, furniture). In developing countries, building materials are often poorly regulated, and the use of unsafe stoves, open fires or kerosene candles in the house is not uncommon. Some interventions within the built environment, such as installing smoke alarms, were successful in reducing fire-related injuries (Cryer, 2001; Millward, Morgan and Kelly, 2003).

Globally, an estimated 7% (5–9%) of fire-related injuries had environmental causes, with workplace factors accounting for about 2% (WHO, 2002; Concha-Barrientos, 2004).

## DROWNINGS

Drownings can be caused by environmental factors, such as risks in the recreational environment and in the built environment (e.g. unprotected wells or house cisterns) (Celis, 1991), by floods, or by non-environmental factors such as alcohol consumption (Giustini et al., 2003; WHO, 2003; Centers for Disease Control and Prevention, 2004). In low-income countries, transportation on waterways is also a hazardous undertaking, owing to a lack of safety measures and regulations, and may play a major role in drownings.

Many drownings could be prevented by known interventions. These include public education and awareness programmes, improving recreational environments in the vicinity of water bodies, enforcing regulations related to water bodies (e.g. to install physical barriers, or to maintain prevention and rescue services), and enforcing regulations for occupational safety (Norris and Wilson, 2003; WHO, 2003).

Although floods are natural events that are exacerbated by climate change (McMichael et al., 2004), many drownings related to flooding could be prevented by dams, appropriate land use patterns, or even longer-term actions to limit climate change. Some alcohol-related drownings could be avoided by implementing safety measures in recreational environments, and by targeted education. Drowning rates have decreased significantly in developed countries over the past decade, coinciding with a period in which interventions related to recreational environments and to education were emphasized. In Italy, for example, drownings were reduced by 75% (Giustini et al., 2003).

For developed countries, it was estimated that 54% (30–76%) of drownings were attributable to the environment or to occupation. In developing countries, where recreational safety, water transportation safety, and flood control were less developed, the corresponding figure was higher (74%; 48–92%). About 1% of all drownings occurred at work (WHO, 2002; Concha-Barrientos, 2004).

### OTHER UNINTENTIONAL INJURIES

This category includes a range of injuries that occur in a variety of circumstances and settings, many of which relate to the environment. The injuries are mainly sustained from:

- contact with mechanical forces (including sports equipment and agricultural machinery);
- off-road transportation accidents;
- animal bites and contact with venomous plants;
- exposure to ionizing radiation or electric currents;
- suffocation;
- natural forces (e.g. floods, storms, periods of excessively hot or cold weather, earthquakes);
- contact with hot substances;
- complications from medical and surgical care.

About 18% of all injuries in this category were attributable to occupation (WHO, 2002; Concha-Barrientos et al., 2004). Another 0.4% were attributable to floods caused by climate change (WHO, 2002; McMichael et al., 2004).

Although floods and earthquakes are natural events, both were included in this analysis because their consequences could in part be ameliorated by environmental measures (e.g. dams, land use patterns, action to limit climate change, use of adequate building materials). In developed countries, it was estimated that 30% (20–40%) of all injuries in this category were attributable to the environment, and 45% (22–76%) in developing countries.

More than 50% of all drownings can be prevented by improving environmental safety and management.



Crowds at a beach in the United Kingdom.

Credit: David Woodfall/Still Pictures

## SUICIDE

Environmental factors affecting access to pesticides or guns may help facilitate suicide. Suicides also may be associated with work-related stress and with stress related to the built or degraded environment (Boxer, Burnett and Swanson, 1995).

Methods commonly used in suicide include: ingesting pesticides or other chemicals, drowning, hanging, shooting (Lester and Murrell, 1980; Kellermann et al., 1992), and gassing with car exhaust, domestic gas (Kreitman, 1976), or charcoal fumes (Chung and Leung, 2001). Modifying the environment, by improving chemical safety, detoxifying domestic gas or limiting access to guns, may therefore significantly reduce suicide incidence (Farmer and Rohde, 1980; Brent et al., 1991; Bertolote, 1993; Bowles, 1995; Leenaars et al., 2000).

The methods of self-harm differed significantly between regions (Farmer and Rohde, 1980; Clarke and Lester, 1987; Gunnell and Eddleston, 2003). As a result, estimates of the fraction of the suicide burden that could be affected by modifying the environment also vary. For example, in rural China, Malaysia, Sri Lanka and Trinidad, the primary method of suicide was ingestion of pesticides (Gunnell and Eddleston, 2003). In certain parts of the USA, gunshot was the main method (Lester and Murrell, 1980; Kellermann et al., 1992), while in England and Wales hanging was a common method (Wilkinson and Gunnell, 2000).

Estimates of the fraction of suicide injuries that could be attributed to the environment were: 22% (7–43%) in the Europe and the Eastern Mediterranean regions, 24% (20–30%) in North America, 18% (15–20%) in Latin America, 36% (20–50%) in developing regions of Asia, 16% (10–30%) in developed areas of the Western Pacific Region, and 10% (5–15%) in the Africa Region (although this estimate was based on few data). Globally, an average of 30% (22–37%) of all suicides were attributable to the environment.

## INTERPERSONAL VIOLENCE

Various environmental factors influence interpersonal violence; interventions in the physical environment could thus reduce levels of interpersonal violence. Examples include reducing access to dangerous items (e.g. type of bar glassware), or reducing access to firearms through safe storage (Hemenway and Miller, 2000; Slovak, 2002). Street lighting may reduce violence by increasing visibility and raising the perceived risk of performing a violent act (Welsh and Farrington, 2004). Certain urban design and land use patterns also may reduce tensions and crime (André and Platteau, 1998).

**Environmental interventions such as improved street lighting can help reduce the level of interpersonal violence.**



Young women walk along a well-lit street in Moscow.

Credit: Transit/Still Pictures

Exposure to certain substances such as lead, can affect neuropsychological development and cognitive functioning, which could also increase delinquent behaviour (Needleman et al., 1996; Nevin, 2000; Dietrich et al., 2001; Stretesky and Lynch, 2001, 2004; Needleman et al., 2002).

Certain dietary choices, including fish consumption, balanced intake of micronutrients, and a good nutritional status overall also have been associated with reduced rates of violent behaviour (Schoenthaler et al., 1997; Hibbeln, 2001; Gesch et al., 2002; Schrauzer, 2002; Liu et al., 2004; Gesch, 2005). Although the consumption of seafood and other nutrients may have environmental components (e.g. related to the availability of fish, or the lithium content of drinking-water), such consumption was not considered to be "environmental" in this study, as the links between nutritional choices, micronutrient intake and the environment are very difficult to assess.

In developed countries, environmental factors accounted for 16% (3–28%) of the injuries from interpersonal violence, and for about 19% (7–31%) in developing countries. The global average was also about 19% (7–31%), as the majority of injuries from violence occurred in developing countries.

## PHYSICAL INACTIVITY

Physical inactivity is a risk factor for noncommunicable diseases including: ischaemic heart disease and stroke; cancers of the breast, colon and rectum; and diabetes mellitus. For these diseases, the attributable fraction for physical inactivity varied between 10% and 22% globally, depending on the disease (WHO, 2002; Bull et al., 2004). The prevalence of physical inactivity can be modulated by the environment, via factors that encourage physical activity (Brownson et al., 2001; Craig et al., 2002; De Bourdeaudhuij, Sallis and Saelens, 2003; Eyster et al., 2003; Huston et al., 2003; Ewing, 2005).

It was estimated that 17% (11–23%, depending on the region) of the global population was inactive, defined as "doing no or very little physical activity at work, home, for transport or in discretionary time". In addition, 41% (32–52%, depending on the region) of the global population had insufficient activity levels (Bull et al., 2004). Insufficient activity has been defined as: "doing some physical activity, but less than 150 minutes of moderate-intensity physical activity, or 60 minutes of vigorous-intensity physical activity, a week, accumulated across work, home, transport or discretionary domains." This means that more than half of the global population gets insufficient physical activity to protect them from related risks causing death, chronic morbidity and disability from a range of noncommunicable diseases. Inactivity levels could be reduced by designing environments that are more conducive to physical activity in the workplace, at home, in transport and in leisure time.

More than half of the global population gets insufficient physical activity to protect them from a range of non-communicable diseases, including heart disease; cancers of the breast, colon and rectum; and diabetes mellitus.



Cyclists at rush hour in Shanghai. Cycling, a very beneficial form of physical exercise, is still a popular means of daily travel in Asia, but there is increasing competition for road space from motor scooters and motor vehicles.

Credit: Julio Etchart/Still Pictures

Transport and urban design measures can reduce the level of physical inactivity, which is a risk factor for several diseases, including heart disease, stroke, cancer and diabetes.



Good public transport systems also can stimulate “active travel” by pedestrians and cyclists going to and from transit stations.

Credit: Topfoto/Image Works

Certain built environments (Transport Research Board, 2005), or related policy measures, may facilitate more active lifestyles, particularly by encouraging walking and cycling. Modifiable factors in the built environment include land use mix and densities, access to key destinations and facilities, transport infrastructure, and building design. Pedestrian-friendly and bicycle-friendly environments include side-walks, ample building setbacks, walking and cycling paths, parks, bus shelters, and streets that are easy to cross. The level of car use in a population is related to the built environment and also has been linked to physical inactivity and obesity (Frank, Andresen and Schmid, 2004). Therefore, measures that discourage reliance on a car also may encourage physical activity, and reduce physical inactivity.

Higher car-related taxes are one such measure that can discourage car use and promote physical activity. In Denmark and the UK, for example, traffic modification measures increased the number of cyclists by about 20% in urban areas (Mayor of London - Transport for London, 2004; Odense Municipality, 2004). In certain developing regions, the potential impact of environmental interventions on physical inactivity levels is likely to be low because rates of motor vehicle ownership are low and much routine travel is by foot or bicycle. Nevertheless, many developing regions are undergoing rapid urbanization and motorization. Thus, the impact of environmental factors on physical activity levels may be very dynamic.

It has been estimated that inactivity levels could be reduced by 31% (12–59%) for North America and developed areas of the Western Pacific region, 27% (12–58%) for the European region, 20% (8–38%) for China, 18% (11–34%) for the Latin America and the Caribbean region, and 13% (3–35%) in other developing regions. Globally, 19% (13–27%) of current inactivity levels could be prevented by environmental interventions.

## OTHER DISEASES

Not all environmental risk factors and related diseases have been included in this analysis. Some diseases and disease groups were not significantly linked to the modifiable environment under the definition used. In other cases, the evidence was too incomplete to make a reasonably sound estimate of quantifiable health impacts. For example, population health impacts associated with environmental exposures to endocrine-disrupting substances were not deemed to be quantifiable at present. Injuries related to wartime conflicts also were not considered. Examples of other diseases or health conditions associated with environmental risks, but where quantification of those health impacts was not deemed to be feasible, include obesity, anaemia, and iodine deficiency.