HK J Paediatr (new series) 2015;**20**:86-94

Invited Article

Environmental Hazards that Matter for Children's Health

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Abstract Healthy children play a crucial role in sustainable development. Currently, profound changes are taking place in the environments in which children are born, play, grow and learn. These changes pose risks to the health of children. The World Health Organization estimates that approximately one third of the disease burden in developing countries is attributed to modifiable environmental factors, including indoor and outdoor air pollution, unsafe water, inadequate sanitation, and hygiene. Children's exposure to these environmental pollutants whether in the form of high-level or low-level will lead to significant morbidity and mortality in short-term or even long-term in adulthood. Exposure of children to the environmental hazards mentioned in this paper is preventable. Paediatricians and healthcare workers should be aware of the associated adverse health effects and work together to reduce and finally eliminate these hazards.

Key words Environmental child health; Environmental hazard; Pollutants

Introduction

Children's exposure to pollutants in the air, water, food and soil – whether in the form of short-term, high-level, or long-term, low-level exposure – is a major contributor to increased morbidity and mortality. The World Health Organization (WHO) estimates that approximately one third of the disease burden in developing countries is attributed to modifiable environmental factors, including indoor and outdoor air pollution, unsafe water, inadequate sanitation, and hygiene. This is 2 to 3 times higher than the attributable portion in the most developed countries. Box 1 shows the WHO definition of the modifiable environment.[1] Figure 1 shows the burden of disease due to air, water, food and soil contamination.[2,3]

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Received March 3, 2015

Outdoor Air Pollution

Children may be exposed outdoors to various mixtures of air contaminants (particulate matter, nitrogen dioxide, sulfur dioxide, ozone, and other photochemical oxidants) depending on where they live and attend school, as well as other factors, such as how near their homes and schools are to polluting industries, power plants, areas of high traffic, and outdoor waste burning. Rapid industrialisation has resulted in very high levels of particulate matter in some Asian cities.[4] Children exposed to outdoor air pollution and very high concentrations of particulate matter have an increased risk of acute and chronic respiratory diseases and decrements in lung function. The smallest particles result in the greatest lung damage. The air quality guidelines in Table 1 are recommended everywhere (indoors and outdoors) to significantly reduce the adverse health effects of pollution.[5] Efforts to reduce coal burning emissions and the environmental impacts of industrialisation have generated measurable health benefits.[6]

Box 1 Definition of the Modifiable Environment

- Air, soil, and water pollution with chemicals or biological agents
- Ultraviolet and ionising radiation
- Built environment
- Noise, electromagnetic fields
- Occupational risks
- Agricultural methods, irrigation schemes
- Anthropogenic climate changes, ecosystem degradation
- Individual behaviours related to the environment, such as hand washing, food contamination with unsafe water or dirty hands

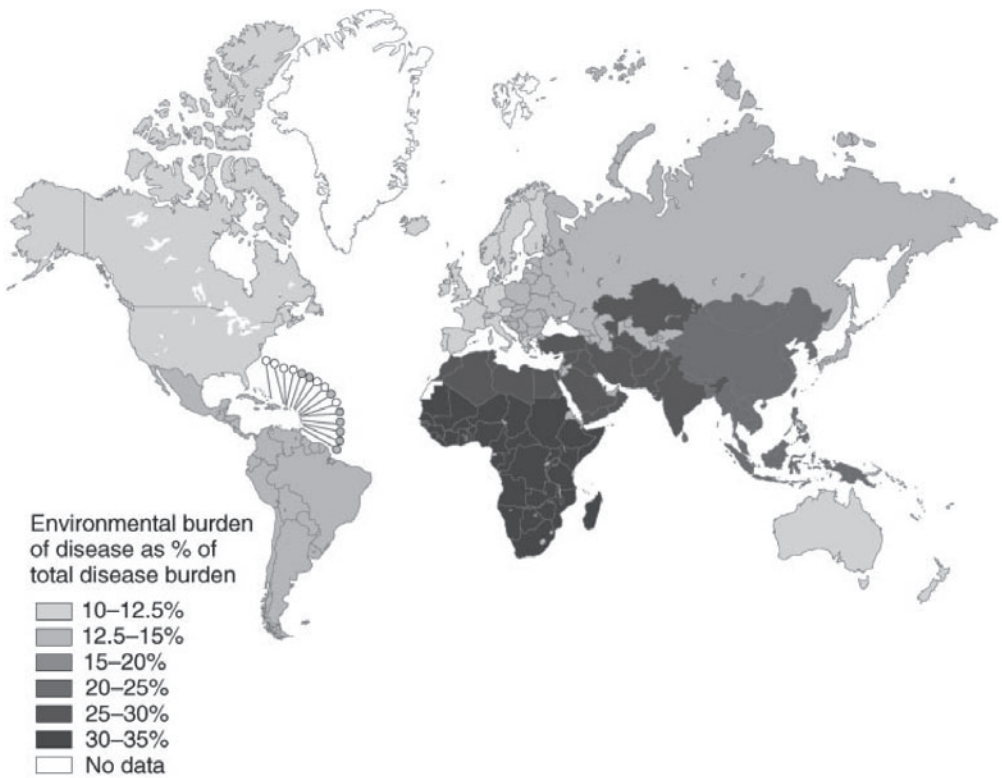
Excluded from the definition: Individual choices, such as alcohol and tobacco consumption, drug abuse, and diet; natural environments that cannot reasonably be modified (rivers, etc.); unemployment (provided that it is not linked to the degradation of the environment); natural biological agents (e.g., pollen); and person-to-person transmission that cannot reasonably be prevented by environmental interventions.

From World Health Organization. Preventing Disease Through Healthy Environments: Towards an Estimate of the Environmental Burden of Disease. http://www.who.int/quantifying_ehimpacts/publications/preventingdisease.pdf.

Table 1 World Health Organization Air Quality Guidelines

Pollutant	Air quality guideline value	Averaging time
Carbon monoxide	100 mg/m^3	15 minutes
	60 mg/m^3	30 minutes
	30 mg/m^3	1 hour
	10 mg/m^3	8 hours
Nitrogen dioxide	200 µg/m^3	1 hour
	40 µg/m^3	Annual
Ozone	100 µg/m^3	8 hours, daily maximum
Sulfur dioxide	500 µg/m^3	10 minutes
	20 µg/m^3	24 hours
Particulate matter		
$PM_{2.5}$	10 µg/m^3	1 year
	25 µg/m^3	24 hours
PM_{10}	20 µg/m^3	1 year
	50 µg/m^3	24 hours

From World Health Organization. Air Quality Guidelines Global Update 2005. http://www.euro.who.int/__data/assets/pdf_file/0005/78638/E90038.pdf.



From World Health Organization. Health and Environmental Linkages Initiative. Priority environmental and health risks. http://www.who.int/heli/risks/en.

Figure 1 Environmental Burden of Disease Globally.

Indoor Air Pollution

Smoke from Biomass Fuel Combustion

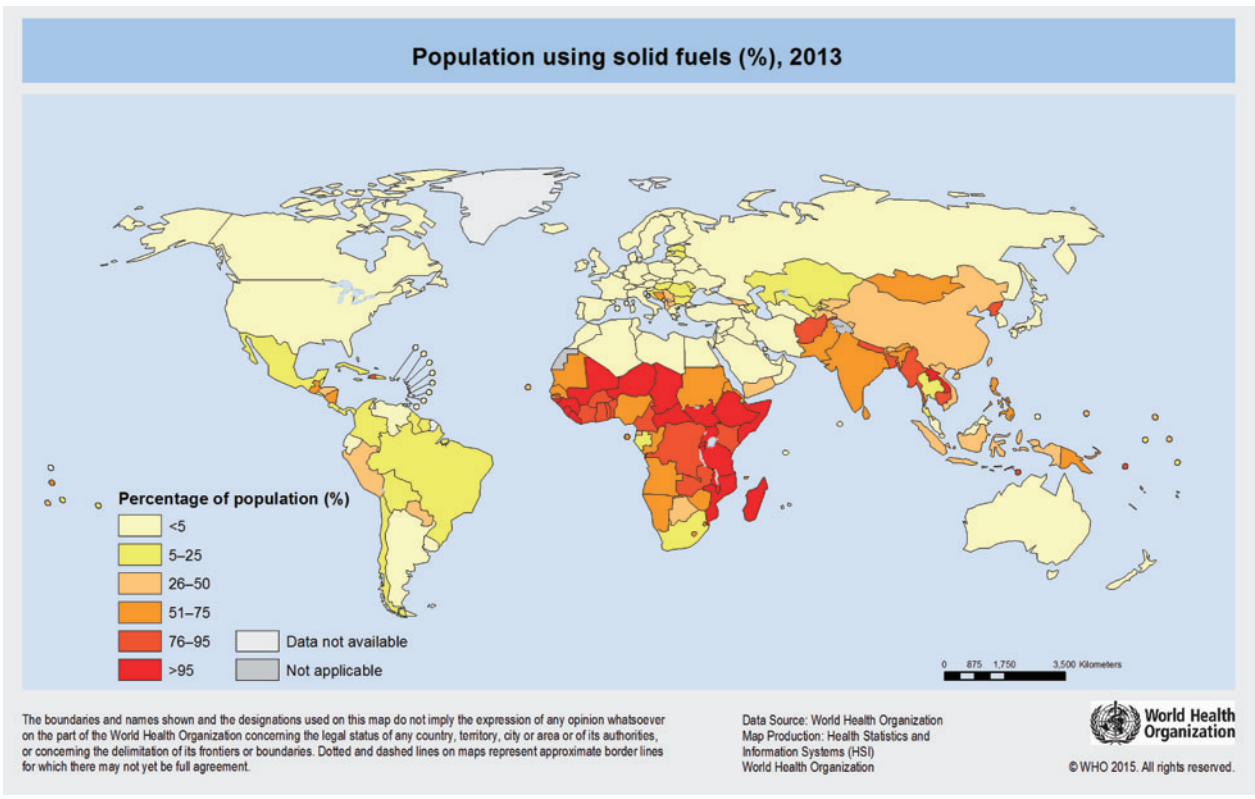
Almost 3 billion people use solid fuels (biomass or coal) for cooking and breathe the air that is heavily polluted from burning these fuels (see Figure 2). Ninety percent of rural households in low-income countries use biomass fuels for cooking or heating. The smoke contains particulates, carbon monoxide (CO), nitrogen oxides, sulfur oxides, benzene, formaldehyde, and polycyclic aromatic hydrocarbons. Indoor concentrations of particulate matter less than 10 µm in aerodynamic diameter (PM_{10}) up to 2,000 µg/m^3 are produced by burning biomass fuel (much higher than the WHO air quality guidelines [Table 1]).[5]

Most of the particulate matter from burning solid fuels is fine particles smaller than 2.5 µm in aerodynamic diameter. Infants and young children spend many hours very close to fires while their mothers cook.[7] High concentrations of indoor air pollution and long periods of exposure increase the risk of lower respiratory illness and tuberculosis among children.[8-11] Globally, 4.3 million deaths were attributable to household air pollution in 2012, almost all in low and middle income countries. Thirteen percent of these deaths (534,000) were among children under 5 years of age, and the deaths were primarily from lower respiratory illnesses.[12]

In addition to cleaner burning stoves and fuels, behavioural interventions, such as keeping children away from the stove while their mother is cooking, using dry wood, and cooking outdoors whenever possible, can help reduce children's exposure to smoke from biomass fuel combustion.[13]

Tobacco Smoke

More than 1 billion adults smoke worldwide. Tobacco, more than any other agent, kills almost 6 million people a year.[14] Tobacco will kill 8 million people a year by 2030; 70% of these deaths will be in developing countries. Around 700 million, (almost half) of the world's children, breathe air that is polluted by secondhand smoke. Secondhand smoke contains particulate matter and more than 4,000 different chemical compounds, many of which are poisons. Exposure to high levels of secondhand smoke causes mucous membrane irritation and respiratory effects that



From World Health Organization. The Global Health Observatory Map Gallery. http://gamapserver.who.int/mapLibrary/app/searchResults.aspx

Figure 2 Shows the population of the world using solid fuels in 2012.

result in rhinitis, cough, exacerbation of asthma, headache, nausea, eye irritation, sudden infant death syndrome, and some cancers.[15,16] Exposure to secondhand smoke may also increase tuberculosis risk.[17] Using data from 192 countries, the WHO estimated the burden of disease worldwide from exposure to secondhand smoke to be approximately 1% of total mortality and 0.7% of total worldwide burden of disease in disability-adjusted life years.[18] There is no safe level of exposure to secondhand smoke. The WHO urged all countries to pass laws requiring that all indoor public places be 100% smoke free.[19] Paediatricians can take an active role in educating parents and supporting smoke-free public policies. Blending smoking cessation counseling with secondhand smoke exposure reduction counseling can increase the attempts to quit made by mothers with young children.[20] Smoke free laws have been associated with substantial reductions in preterm births and hospital admissions for childhood asthma.[21]

Carbon Monoxide

Carbon monoxide is produced by incomplete fuel combustion. Sources of CO include heating and cooking fuels, automobile exhaust and cigarettes. The symptoms and signs of mild CO poisoning (headache, nausea, vomiting, light-headedness, general malaise, dyspnoea, confusion, and syncope) are nonspecific and may resemble influenza, tension or migraine headache, gastroenteritis, food poisoning, or depression. Children with higher exposures to CO may have seizures, coma, or dysrhythmias. A high index of suspicion is needed to identify CO poisoning.

Biological Particles

Exposures to airborne biological matter, including pollen and fungi, are associated with increased respiratory illness in children. Exposure to high levels of airborne fungi in damp and water-damaged indoor environments is linked to asthma exacerbations in children[22] and acute pulmonary haemorrhage in infants.[23]

Other Contaminants

Lead

Children can be exposed to lead from a wide variety of sources. Leaded gasoline (petrol) was previously a major source of lead exposure. Currently, all but 4 countries have phased out leaded gasoline. Children also may be exposed from the use of lead ore in eye cosmetics and from lead in ceramic dishes or paint. Lead paint has long been outlawed in developed countries, but no legislation prevents lead paint from being sold in many parts of Asia and India.[24] Children may be exposed from backyard cottage industries (e.g., battery recycling).[25] Children also may be exposed from living or playing near areas where mining occurs. A mass lead intoxication in northern Nigeria during 2010 resulted in the deaths of more than 200 children whose parents were engaged in small-scale gold mining activities.[26]

Lead is toxic to the nervous system; effects are particularly severe during the early development of the central nervous system.[27] Children with elevated lead levels have lower intelligence scores, more language difficulties, attention problems, and behaviour disorders.[27] These adverse effects on intellectual development of children are seen at blood lead concentrations below 10 μg/dL.[28] In 2012, the US Centers for Disease Control and Prevention defined a reference level of 5 μg/dL to identify children with elevated blood lead levels. Blood lead concentrations well above this level are frequently reported in children from Africa and Asia.[29,30]

Mercury

Children in low- and middle-income countries may be exposed to mercury from many sources.[31] For example, mercury is used in small-scale gold-mining activities. Gold is extracted using mercury amalgamation, which poses a threat to human health.[32] Unmonitored releases of mercury from gold amalgamation has caused considerable environmental contamination and human health complications in the Amazon basin in South America and in rural sub-Saharan Africa.[33,34]

Skin lightening (bleaching) cosmetics and toiletries are widely used in some countries. The active ingredients in these cosmetic products are mercury, hydroquinone, and corticosteroids. Skin absorption of mercury is enhanced because these products are used for a long duration on a large body surface area and under hot and humid conditions; fatalities have occurred.[35]

Waste Sites

Uncontrolled hazardous waste sites may pose a hazard to children; these sites include waste storage and treatment facilities, landfills, former industrial sites, military facilities, waste recycling facilities, and unsanctioned wastewater discharge. Some of the substances found in uncontrolled waste sites include heavy metals such as lead, chromium, and arsenic, and organic solvents such as trichloroethylene and benzene.

Chemicals from Electronic Waste

Poor countries have become a destination for electronic waste (e-waste), including many tons of used desktop computers, fax machines, cell phones, and other electronic equipment. Although many of these machines can be repaired and resold, up to 75% of the electronics shipped to Africa is junk.[36] When dumped, this equipment may leach lead, mercury, and cadmium into the environment; when burned, it may release carcinogenic dioxins and polyaromatic hydrocarbons into the air.[37] Children living in towns where primitive e-waste recycling occurs may have high blood levels of lead and cadmium.[38] Negative associations between blood chromium concentrations and forced vital capacity have been documented among children aged 11 and 13 years from an e-waste recycling area.[39,40]

Pesticides

Pesticides (especially anticholinesterase-type) are among the most common causes of acute poisonings among children in some low-income countries.[41] Even at low levels, these pesticides adversely affect children, including neurotoxicity and possibly endocrine disruption. Children heavily exposed to pesticides performed significantly worse on developmental tests than those less heavily exposed.[42]

Some of the older pesticides were designed to persist and can still be found in water and soil worldwide. Newer pesticides degrade more quickly but still contaminate water and soil and, consequently, food.

Water Pollution

Contaminated water causes a range of water-related diseases. A variety of viruses, bacteria, and parasites can contaminate drinking water and cause gastrointestinal diseases in infants and young children. Mortality and morbidity due to waterborne gastrointestinal diseases, mainly diarrhoeal, are still high in countries and communities where a substantial proportion of the population does not have access to proper water and sanitation. Effects from a lack of safe water and sanitation may also be indirect and long term; e.g., repeated gastrointestinal infections represent a secondary cause of impaired growth, cognitive development, and school performance.[43,44]

Arsenic

Children are exposed to arsenic mainly through drinking water. Arsenic is naturally high in water in some areas of the world, including West Bengal, India; Bangladesh; Mongolia; China; Chile; and some parts of Africa. Arsenic is deposited in river systems over thousands of years from arsenic-rich material. Approximately 45 years ago, local authorities installed tube wells in Bangladesh and other areas to provide a clean source of drinking water uncontaminated by biological agents. In 1993, however, high levels of arsenic were discovered in the ground water in Bangladesh. A testing program revealed that about 1 in 5 tube wells were using water with high arsenic levels (greater than 50 parts per billion). A massive information campaign is teaching people in Bangladesh about the dangers of drinking water with high arsenic levels.[45]

In addition to its natural presence in water, arsenic is also produced by a variety of activities, such as smelting and coal burning. Food crops, such as cassava, cocoyam, and other tuber crops grown in communities with mining and smelting activities, can take up arsenic from the soil.[46] Arsenic also is found in some herbal remedies.[47-49]

Overt symptoms of arsenic poisoning are rare in children but are seen in children as young as 3 years in Inner Mongolia.[50] After 20 or more years of exposure to high arsenic levels in drinking water, arsenic causes bladder, kidney, lung, and skin cancers. Neurologic effects, cardiovascular and pulmonary disease, skin lesions, and diabetes are also associated with arsenic exposure from drinking water.[51-53]

Fluoride

Drinking water in some parts of the world is contaminated with high levels of fluoride. Fluorosis is a potentially crippling disease caused by ingesting too much fluoride. Fluorosis is widespread in the eastern part of Africa and some parts of China. High concentrations of fluoride in water can affect children's growth and intelligence.[54] Endemic goiter in children living in 6 villages in South Africa was associated with an excess of fluoride in the drinking water, presumably due to its influence on thyroid hormones.[55] Although drinking water is traditionally considered the main source of fluoride, food items may be a contributing factor in areas with high concentrations of fluoride in the soil.[56]

Food-borne Hazards

Contamination of food with viruses and bacteria is a major cause of food-borne illnesses. Children are also at risk from a variety of chemical food-borne hazards in the environment, which include natural hazards such as mycotoxins and persistent organic pollutants.

Mycotoxins

Mycotoxins are toxic chemicals produced by certain fungi that can grow on crops in the field or during storage. Growth of fungi on grains, nuts, and other crops is influenced by temperature, humidity, and rainfall. Mycotoxins can harm children's immune systems and lead to acute respiratory illness, gastrointestinal illness, tremors, and cancer.

Aflatoxins

Aflatoxins are poisonous substances that occur as a result of mould growth on peanuts and corn. High levels of aflatoxin cause acute aflatoxicosis.[57] Aflatoxin exposure during pregnancy results in poor growth in the child's first year of life.[58]

Ochratoxin A

Ochratoxin A, produced by some moulds, is toxic to the kidneys. Ochratoxin A contaminates many foods, including cereals, cereal-derived foods, dry fruits, beans, cocoa, coffee, beer, wine, poultry, eggs, pork, and milk. Ochratoxin A is teratogenic, immunotoxic, genotoxic, mutagenic, and carcinogenic.

Fumonisins

Fumonisins are contaminants of cornmeal and cereals. Eating foods contaminated with fumonisins increases the risk of having a child with a neural tube defect and the risk of developing oesophageal cancer during adulthood.

There is a need to ensure that children's foods do not contain excessive amounts of aflatoxins, ochratoxin A, or fumonisins.[59] This is especially important considering the emerging evidence linking mycotoxin exposures to stunted growth in children. [60]

Other Chemicals

Persistent Organic Pollutants

Persistent organic pollutants include compounds such as polychlorinated biphenyls and dioxins, which are very resistant to biological degradation and remain in the environment for decades. The major source of children's exposure to persistent organic pollutants is through food.[61] The effects of these chemicals include neurotoxicity and carcinogenesis.

Mercury

Mercury comes from combustion sources such as municipal waste incinerators and coal-burning power plants because coal contains mercury. The mercury is deposited into lakes and rivers and converted into methylmercury by bacteria, which then accumulates in fish that mothers and children eat. Methylmercury is toxic to the nervous system and can produce adverse neurodevelopmental effects on the fetus through the maternal diet.[15]

Radiation

Ionising Radiation

Children can be significantly exposed to ionising radiation from radioactive fallout (ie, after disasters such as those at the Fukushima and Chernobyl nuclear power plants)[62] and medical diagnostic equipment (i.e., X-ray and radioisotopes). Abandoned medical scanners, food processing devices, and mining equipment that contains radioactive metals such as Cs-137 and Co-60 are often picked up by scrap collectors and sold to recyclers. Such items may be hidden inside beer kegs and lead pipes to prevent detection. Smelting these items contaminates recycled metal used to make new products (including consumer goods) and the furnaces that process the material. Many atomic devices were not licensed when they were first widely used by industry in the 1970s.

Acute effects of overexposure to ionising radiation include acute radiation sickness (nausea, vomiting, diarrhoea, declining white blood cell count, and thrombocytopenia), epilation (loss of hair), and death. Delayed effects are largely caused by mutagenesis, teratogenesis, and carcinogenesis. Ionising radiation causes chromosome breaks in somatic cells (e.g., lymphocytes, skin fibroblasts) that presumably account for the increased rates of cancer observed after exposure in childhood or adulthood.[63]

An excess of thyroid cancer occurred in Japanese children who were exposed to the atomic bomb beginning at 11 years of age. Thyroid cancer developed in hundreds of children in Ukraine and Belarus after a latent period of only 3 years following the partial meltdown of the nuclear reactor in Chernobyl in 1986.[64] Intrauterine exposure to ionising radiation may cause small head size alone or severe mental retardation. Children are more sensitive to radiation than middle-aged adults by a factor of 10.[65] The health effects are greater if children are iodine deficient.

Radon

Children are constantly exposed to radon, which accounts for a large proportion of background radiation. Radon gas comes from radioactive decay of radium,

a product of uranium deposits in rocks and soil. Radon enters homes through cracks in the foundation, porous cinderblocks, and granite walls. Most of the dose of radon and radon decay products is delivered to the lungs, resulting in an increased risk of lung cancer during adulthood; some of the dose goes to the bone marrow. One study has documented an increased risk of leukemia or cancer among children living in an area with high indoor radon concentrations.[66] Paediatricians should advise families about the hazards of radon exposure and point out that cigarette smoking adds to the radon-induced risk of lung cancer.

Global Climate Change

Many of the main global killers, such as malaria, diarrhoea, and malnutrition, are closely associated with climatic conditions. Climate change will affect children's health as a result of their exposure to extreme temperatures and precipitation; food insecurity; transmission rates of vector-borne diseases; and increases in air pollution from molds, pollens, and the burning of fossil fuels.[67] Food insecurity, water scarcity, damp housing, water- and vector-borne diseases, mycotoxin-related illnesses, and natural disasters such as floods and hurricanes will worsen as temperatures and sea levels rise. The impacts will be felt most among young children in low and middle income countries.

Exposure of children to the environmental hazards mentioned in this paper is preventable. Paediatricians need to be aware of the adverse health effects from these hazards and work toward their control and eventual elimination.

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