Chapter 6

Health Effects of Changing Environment

Randeep Guleria, Vartika Mathur, and Ashutosh Dhanuka

Abstract Environment plays a crucial role in our economic, social and cultural behaviour as well as on health. However, since the beginning of industrialization era, focus on economic development has caused detrimental effects on the environment. Last two centuries have witnessed changes in global environmental factors such as rise in temperature leading to global warming, depletion of stratospheric ozone layer, loss of biodiversity and marked degradation in air and water quality due to atmospheric pollution, thereby causing upsurge in infectious and non-infectious diseases. Environmental health has emerged as an important part of medicine. The World Health Organization (WHO) estimates that 24% of global disease burden and 23% of all deaths can be attributed to environmental factors. Deaths from heart disease, cancer, respiratory disorders and many vector-borne diseases such as malaria, dengue, chikungunya and cholera have increased due to changes in climate, especially in developing countries. Besides limited attention to sanitation, hygiene, as well as quality of food and drinking water, factors such as deforestation, increasing vehicular traffic, migration from rural to urban areas, decreasing water resources and inadequate drainage systems contribute to increase incidence of diseases. The need of the hour is to sensitize ourselves about the way our ecology is being degraded and the health effects it is causing. A holistic view is needed to address the problem of environmental health where agriculture, animal husbandry, public health, water safety and air pollution need to be looked at in a combined manner for education, planning and resource allocation. Therefore, a close

R. Guleria

Department of Pulmonary Medicine and Sleep Disorders, All India Institute of Medical Sciences, New Delhi, India

e-mail: randeepguleria2002@yahoo.com

V. Mathur (✉)

Department of Zoology, Sri Venkateswara College, University of Delhi, New Delhi, India

e-mail: vmathur@svc.ac.in

A. Dhanuka

Geetanjali Medical College and Hospital, Udaipur, India

e-mail: ashutruth@gmail.com

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association between scientists, public health professionals and administrators is needed for integrated design and development of framework to attain harmony between man and nature.

Keywords Pollution · Infectious diseases · Indoor pollution · Changing climate · Air pollution · Water pollution

Abbreviations

AIIMS	All India Institute of Medical Sciences
COPD	Chronic obstructive pulmonary disease
ENSO	El Niño Southern Oscillation
IPCC	Intergovernmental Panel on Climate Change
WHO	World Health Organization

6.1 Introduction

An ecosystem is defined as a community of living beings surviving and interacting in mutual and interdependent relationship with their physical environment. For thousands of years, man has lived in harmony with their natural surroundings. Environment has played a crucial role in his economic, social and cultural behaviour as well as on his health. The role of environment in various diseases has been well documented, both in communicable and non-communicable diseases. Since the dawn of industrialization era in Europe 400 years ago and its subsequent spread to the rest of world, economic development and physical comfort for mankind have increased at a tremendous pace. This increase is perhaps the most rapid over the last three decades. Often this has been done, knowingly or unknowingly, at the cost of our environment. The last 200 years have witnessed a sharp increase in the global temperature from its levels around 4000 years ago, owing to industrialization (Mann et al. 2008; Marcott et al. 2013). Moreover, other concerns such as depletion of carbon fuels at alarming rates, damage to the ozone layer and rise in seawater levels, combined with global warming, have damaged our environment extensively, leading to changes in the aquatic biodiversity and to the extinction of many species of plants and animals (Thomas et al. 2004). Increase in urbanization has led to loss of dense forests. Air pollution has risen to the extent that many big cities in the world have a highly toxic air quality. However, very little has been done by various governmental and non-governmental agencies with almost no visible results. The need of the hour is to sensitize the scientific community, as well as the common man, about the way our ecology is being degraded and the health effects it is causing and to suggest ways to get remedies for this situation.

Environmental health has emerged as an important part of medicine, due to the rapid environmental changes linked to industrialization and urbanization. It is being increasingly recognized that environmental factors play a key role in human health and are linked to many chronic and infectious diseases. Deaths from heart disease and respiratory illness are increasing, and many diseases such as malaria, dengue, chikungunya and cholera are sensitive to changes in the climate (McMichael et al. 2006; Patz et al. 2005).

According to the World Health Organization (WHO), 'In its broadest sense, environmental health comprises those aspects of human health, disease and injuries that are determined or influenced by factors in the environment. This includes the study of both direct pathological effects of various chemical, physical and biological agents, as well as effects on health of the broad physical and social environment, which include housing, urban development, land use and transportation, industry and agriculture'. The WHO estimates that 24% of the global disease burden and 23% of all deaths can be attributed to environmental factors. Moreover, environmental factors have a much bigger impact in developing countries than developed ones, and this effect is seen much more in the vulnerable population such as children and elderly.

In a developing country like India, the burden of various diseases is increasing due to environmental factors and the changes in our environment. It is estimated that 94% diarrhoeal disease burden may be attributed to environmental factors such as unsafe food and drinking water, as well as poor sanitation and hygiene. Similarly, in India there is strong evidence linking lower respiratory tract infection to indoor air pollution caused by the use of solid fuels in household. Almost 42% of acute lower respiratory tract infections in developing countries are attributable to environmental factors. Besides this, a close association of vector-borne diseases and environmental conditions has been established. Furthermore, factors such as deforestation, increasing vehicular traffic, migration from rural to urban areas, decreasing water resources and inadequate drainage system are important environmental and ecological factors that contribute to infectious diseases.

6.2 Temperature Changes

The temperature of the earth has increased by about 0.6 °C over the past 100 years (Griggs and Noguer 2002; McCarthy 2001). Winters are shortening and average temperature is rising. Intergovernmental Panel on Climate Change (IPCC) of United Nations predicts that the global temperature will rise by 1.8–5.8 °C by the turn of this century, if no remediable actions are taken (Houghton et al. 2001). This will lead to rise in sea level by 9–88 cm and drowning of coastal cities, which comprise 50% of world's major cities (Crutzen 2006; FitzGerald et al. 2008; Nicholls and Cazenave 2010). Higher temperatures will lead to melting of polar ice, melting of glaciers, floods and droughts (Patz et al. 2001). Average temperature shall rise during both summers and winters. Heat waves will increase, and average annual

precipitation will also increase correspondingly. Heat waves, floods and droughts lead to natural calamities, shortage of food supplies, increased risk of infectious diseases and increased human mortality (Haines et al. 2006).

6.3 Water Extremes and Pollution

Clean water is essential for the survival of humans. Water pollution due to environmental changes therefore constitutes another serious risk to the health of our planet. Water pollution occurs when energy and substances are released and degrades the quality of water for other users. Anything that is added to water, which is more than its capacity to break it down, constitutes water pollution. Anthropogenic activities such as industrial waste effluents, sewage disposal and agricultural activities are some of the major causes of water pollution (Manivasakam 2005; Tilman et al. 2001). Chemical pollution of surface water causes major health problems as it can be used directly for drinking or it may contaminate shallow wells, used for drinking. Ground water, which is much deeper, has very few pathogens as it gets filtered when it passes through many underground layers. It can be polluted by toxic chemicals such as fluoride and arsenic which may be present in the soil or the rock layers. Similarly, pollution of coastal water can cause contamination of sea food (Guleria 2013). Changing environment has a serious effect on safe water, affecting not only human health but also changing the ecology of plants. The global effect of water pollution has not been studied in detail and is limited to mainly outbreaks of waterborne infections or certain chemical toxins in limited areas, such as arsenic in drinking water in Bangladesh, 'Minamata' disease in Japan, etc. (Argos et al. 2010; Harada 1995). The burden of waterborne diseases is grossly underreported in India due to lack of data, poor surveillance and reporting. According to a report from the Ministry of Health and Family Welfare, nearly 40 million people are affected by waterborne diseases such as diarrhoea, enteric fever, amoebiasis and helminthic infestations, every year. WHO estimates >330,000 deaths annually, in India alone, due to contaminated water consumption. Moreover, floods and droughts also affect human health. Floods lead to physical injury as well as spread of waterborne diseases such as diarrhoea, enteric fever and viral hepatitis. Overcrowding occurs and sanitation is affected, leading to respiratory infections. Diseases such as malaria and dengue may turn into epidemics. On the other hand, drought leads to lack of sanitation, decreased food production and ultimately malnutrition.

Another aspect of waterborne diseases is chemical contamination leading to diseases such as fluorosis and methemoglobinemia, due to contamination of soil water owing to fluoride and fertilizers. Chronic exposure to contaminated water can cause significant health effects and can lead to liver and kidney damages. This occurs due to chronic exposure to copper, cadmium, arsenic, mercury, chromium and chlorobenzene. Endocrine effects have been reported, and problems relating to reproduction, development and behaviour have also been observed.

6.4 El Niño Southern Oscillations (ENSO)

ENSO is a cycle of seawater temperature and pressure changes occurring over the southern Pacific Ocean at an interval of 2–7 years and lasting for 6–18 months. This leads to episodes of floods in the southwest United States, Mexico and Western coast of Latin America and droughts in Southeast Asia and the Pacific islands (Kovats et al. 2003). This may be followed by cold waves called La Niña. Higher global temperatures are predicted to lead to more frequent and severe ENSOs, and this will lead to significant effects on human health, in the coming years (Bouma et al. 1997).

6.5 Infectious Diseases and Environment

Change in the global climate has led to higher temperatures, humidity and floods, which has made the environment more conducive for parasites such as mosquitoes and fleas (Patz et al. 2000). Malaria, dengue and other vector-borne diseases are expected to increase both in magnitude and their geographical reach (Haines et al. 2006). People living at higher altitudes may also likely experience resurgence in vector-borne diseases, due to a rise of average temperatures in these regions. Moreover, these diseases can spread to any part of the world in a very short time (at times during the incubation period) and cause an outbreak in a community where these diseases do not usually occur, resulting in diagnostic difficulties. This has recently been seen during the Ebola and the MERS coronavirus outbreaks. Other factors such as breakdown of public health infrastructure, shortage of medical supplies and changes in land use also contribute to adversities in health, due to water pollution.

6.6 Air Pollution

Air pollutants affect the human body through the inhalational route. Environmental changes due to industrialization have drastically altered the quality of the air we breathe. There are hundred substances that pollute the air and may harm human health. Pollutants are generally classified as primary or secondary pollutants. Chemicals that are directly emitted from a source are known as primary pollutants. These include sulphur dioxide, nitrogen oxides, carbon monoxide, volatile organic compounds, etc. Moreover, particulate matter emitted due to combustion from automobile exhaust, heating, cooking and industrial sources are also primary pollutants. Secondary pollutants, such as formaldehyde, nitric acid and different aldehydes, on the other hand, are formed from chemical or photochemical reaction in the atmosphere. On exposure to sunlight, volatile organic compounds and nitrogen oxides react photochemically, producing pollutants such as ozone.

Air pollution and occupational exposure may cause a variety of negative health outcomes, including reduced lung function in children as well as increased susceptibility to infections, airway inflammation and cardiovascular diseases. Respiratory disorders due to air pollution are emerging to be a major contributor to mortality, according to recent epidemiologic studies. Moreover, low-level air pollution is recently being recognized as a risk factor for lung diseases and death from COPD (Bosson and Blomberg 2013). With newer insights into the immunopathogenesis of asthma, the contribution of air pollution to allergen sensitization and airway hyper-responsiveness are being established. For example, increased exposure to nitrogen dioxide during infancy correlates with increased risk for asthma in later childhood. Ozone can produce significant adverse effects on human health (Gryparis et al. 2004; Teague and Bayer 2001; Uysal and Schapira 2003). Moreover, recent research is now linking air pollution to increased risk of respiratory symptoms and duration of respiratory tract symptoms. International Agency for Research on Cancer recently designated diesel exhaust as a human carcinogen.

Sulphur oxides are produced mainly from industrial activities processing materials that contain sulphur, such as generation of electricity from coal, oil or gas, as well as by combustion of fossil fuels. Sulphur dioxide is also present in motor vehicle emission. Together with ozone, it is known to cause foliar injury and reduction in plant growth (Smith 2012; Tingey and Reinert 1975). It is mainly absorbed in the upper airways as it is water soluble. Its exposure is known to cause symptoms such as nose and throat irritation. It may travel to the lower airways and cause bronchoconstriction and dyspnoea, especially in asthmatic individuals, thus worsening their condition (Balmes et al. 1987; Ierodiakonou et al. 2015).

Nitrogen oxides are emitted primarily from motor vehicle exhausts, as well as from stationary sources such as electric utilities and industrial boilers. Compounds such as sulphur and nitrogen oxides cause chemical reactions in air and acid rains. Although acid rains do not affect humans radically, they may indirectly cause health problems, particularly difficulty in breathing and, in extreme cases, lung problems such as asthma or chronic bronchitis. Moreover, nitrogen oxides are the main precursors in the formation of tropospheric ozone. They also form nitrate particles and acid aerosols. Exposure to nitrogen dioxide for a short term leads to changes in airway responsiveness and deterioration in pulmonary function in individuals with underlying lung disease. Long-term exposure may lead to increased chances of recurrent respiratory tract infections and alter lung mechanics (Berglund et al. 1993).

Carbon monoxide is produced mainly due to motor vehicle emission. In urban areas more than 80% of the carbon monoxide emission may be due to motor vehicles. Besides this, the combustion of coal, oil and gas also leads to carbon monoxide production. Moreover, tobacco smoke is one of the main sources of indoor pollution of carbon monoxide. High levels of carbon monoxide are extremely dangerous to humans, more so because it is colourless, tasteless and odourless and therefore cannot be detected by humans. Early symptoms of carbon monoxide include weakness, headache, nausea, dizziness, confusion, disorientation and visual instability. Carbon monoxide quickly enters the blood stream and forms carboxyhaemoglobin which causes more systemic effects. It reduces oxygen delivery to the tissues and may

have a serious health threat to those with underlying heart disease (Badman and Jaffé 1996). Prolonged or severe exposure may result in lethal arrhythmias, electrocardiographic changes, pulmonary oedema, various neurological symptoms as well as death, most likely due to cardiac failure. Carbon monoxide is known to cause foetal development disorders, brain lesions and, in extreme cases, even mortality (Raub et al. 2000).

The atmospheric levels of lead have decreased due to the use of unleaded fuel. However, lead toxicity continues to be a problem, due to the exposure occurring in drinking water. Lead exposure leads to adverse effects on the central nervous system, causing neurological symptoms such as sleep disorders, fatigue, trembles in limbs, blurred vision and slurred speech, as well as kidney and liver disorders (Kampa and Castanas 2008). Lead toxicity can lead to lower intelligence, learning deficits and behavioural disturbances.

Ozone is an important secondary pollutant and is a component of photochemical smog. It is a pulmonary irritant and an oxidant. It may produce significant adverse effects on human health. Exposure to ozone causes airway inflammation, airway hyperreactivity and a decline in lung functions. Ozone exposure causes cough, chest tightness and wheezing. The increase in the levels of tropospheric ozone is associated with reduced baseline lung functional as well as structural abnormalities, exacerbation of asthma and premature mortality. Recent studies have shown increased admissions for chest complaints and worsening of asthma on exposure to even low levels of ozone. Studies looking at long-term exposure to ozone suggest that a cumulative long-term exposure in childhood may affect lung function, especially that of the small airways of the lung, in adult life (Künzli et al. 1997).

Ozone also affects mucous membrane and causes pulmonary inflammation and has both a local and systemic effect on the immune system. Patients with underlying respiratory illness such as asthma and chronic obstructive airway disease are more prone to the harmful effect of ozone. High ozone concentrations have been linked with increased hospital admissions for pneumonia, COPD and asthma (Gryparis et al. 2004; Teague and Bayer 2001; Uysal and Schapira 2003).

Particulate matter consists of liquid or solid mass contained in an aerosol. It is a mixture of numerous different chemicals, with varying properties. Major sources of particulate matter are factories, power plants, incinerators, motor vehicles, construction activities, fire and dust. Broadly particulate matters from 2.5 to 10 μm in diameter are coarse particulate matter. Coarse particulate matter consists mainly of airborne soil dust and elements such as silicon and aluminium. Fine particles of less than 2.5 μm are composed mainly of sulphate and organic material. Particulate matter in air is associated with allergic rhinitis, lung inflammation, pulmonary disorders, cardiac arrhythmia, ischemic cardiovascular events, higher incidences of cancer and shortening of life (Carlsten and Georas 2014; Dockery et al. 1993; Kampa and Castanas 2008; Pope III et al. 1995; Raaschou-Nielsen et al. 2013).

Only recently we began to understand the cardiovascular effects of air pollution. High levels of air pollution worsen underlying heart disease. But now it is becoming clear that persistent exposure to high levels of air pollution may also lead to heart disease. This is especially true for particulate matter. Inflammation in lungs also

Fig. 6.1 Adverse cardiovascular effects of air pollution

causes inflammation in the blood, leading to atherosclerosis and an increase incidence of coronary artery disease that may be fatal (Fig. 6.1). Many well-conducted studies have demonstrated a 12–25% higher risk of coronary artery disease in individuals exposed to high levels of air pollution, for many years (Cesaroni et al. 2014; Miller et al. 2007). This increased risk has been linked to higher levels of PM_{2.5} in the ambient air. Studies have also looked at subclinical atherosclerosis, which is the pathological process associated with coronary artery disease. A positive association between subclinical atherosclerosis in the carotid and the coronary arteries has been observed with long-term exposure to high levels of air pollution (Künzli et al. 2010; Künzli et al. 2005). There is therefore now a significant body of evidence linking air pollution to cardiovascular diseases and increased mortality. Many investigators argue that air pollution should now be considered as a preventable risk factor like smoking and dyslipidemia for the development of coronary artery disease, and steps should be taken to bring down the exposure to air pollution.

Indoor air pollution and its effect on human health are important as individuals spend more than 50% of their time indoors. Cooking is an integral part of indoor

human activity. The WHO has estimated that about 50% of the world's population, or about 3 billion people, still uses solid fuel for their household energy needs. Of these, about 2.4 billion people use biological material (wood, charcoal, crop waste and dung), and the remaining use coal. In India, about 58% of the population has been estimated to depend upon wood, and about 11% depend upon dung for energy. Although this number is slowly decreasing and moving towards the use of other fuels such as liquefied petroleum gas (LPG) and kerosene, it is still very significant. In India in 2010, of the 1.2 billion people, about 700 million still used solid fuel for cooking or heating. Many studies over the last three decades have documented the link between solid fuel exposure and different respiratory diseases. Lim et al. (2012) estimated more than 100 million premature deaths per year due to indoor air pollution, because of solid fuel used for cooking purposes. Exposure to high concentrations of harmful substances in smoke during use of biomass fuel causes significant illness amongst homemakers and young children. It has been shown that biomass fuel is a less efficient means of energy production and a number of carcinogenic constituents are released during biomass combustion (Chafe et al. 2014; Smith and Sagar 2014). Inhalation of these particles in high concentration leads to 'lung overloading' and sustained inflammation. This results in the release of reactive oxygen that causes Deoxyribonucleic acid (DNA) damage. Indoor smoke produced due to burning of solid fuel contains many pollutants. Particulate matter, nitrogen oxides, carbon monoxide, benzene, 1,3 butadiene, polycyclic aromatic hydrocarbons, free radicals and volatile organic compounds are many of the toxic substances that have been found in smoke produced by burning solid fuels. Chronic exposure to these harmful substances leads to lung fibrosis and subsequently the development of lung cancer. The evidence for the development of lung cancer due to biomass exposure has been shown in experimental animals, but the evidence in humans is not that strong.

Indoor air pollution thus accounts for a significant proportion of the global burden of disease in developing countries. The link between solid fuel exposure and chronic obstructive lung disease in women and acute respiratory tract infection in children is strong. The commendable initiative by the government of India called 'give it up' is a step in trying to decrease the effects of indoor air pollution on human health. Also steps to improve ventilation in kitchens or use smokeless stoves *chulla* may also help in reducing the exposure to indoor air pollution (Reddy et al. 2004).

6.7 Electronic Waste (E-Waste)

Waste generated from used electronic devices and household appliances constitutes e-waste. It comprises of a wide range of equipments and devices falling under 'hazardous' and 'non-hazardous' categories such as computers, mobile phones, refrigerators, washing machines, air conditioners, personal stereos, consumer electronics, etc., that are discarded by users (Puckett et al. 2013). Pollution due to electronic and electrical waste has rapidly grown over the last decade due to progressive increase in production of electronics, lack of proper disposal facilities in India and dumping

of e-waste from developed countries. In 2010 alone, India generated about 0.4 million tons of e-waste (double the amount as compared to 2006), which is progressing rapidly. E-waste may contain many toxic substances which may be harmful to the environment and human health. This can have a significant economic and social impact on society. Iron and steel constitute about 50% of the e-waste followed by plastics (21%), nonferrous metals (13%) and other constituents (10%). Others include nonferrous metals like copper, aluminium, silver, gold, platinum, palladium, etc. The presence of elements such as lead, mercury, arsenic, cadmium, selenium and hexavalent chromium, with flame retardants beyond threshold quantities of e-waste, classifies them as hazardous waste. Manual recycling of e-waste is done predominantly via the unorganized sector, and the work force involved consists predominantly of individuals with low literacy and hardly any training to protect themselves from ill effects and to identify warning signals of toxicity. Accordingly, a significant percentage of health problems due to e-waste results from direct contact with harmful materials and inhalation of toxic fumes. Moreover, these materials may get accumulated in the food and water and are consumed. Heavy metals such as lead can cause kidney failure, neurologic manifestations and hypertension. Mercury toxicity can lead to central and peripheral nervous system damage and hepatic and renal toxicity (Guleria 2013).

Furthermore, uncontrolled burning, disposal and dismantling of e-waste can cause a number of problems including air pollution and water pollution. There is a lack of an environmentally effective recycling infrastructure for e-waste, and this leads to pollution of the environment. This is gradually changing our ecology. There is, therefore, a need to increase public awareness about the harmful effects of e-waste and develop an effective recycling and disposal plan, to prevent or minimize air and water pollution.

6.8 Conclusion

There should be general awareness of how changes in climate and environment lead to significant acute and chronic effects on human health. These effects can be both for infectious and non-infectious illnesses. A holistic view is needed to address the problem of environmental health where agriculture, animal husbandry, public health, water safety and air pollution need to be looked at in a combined manner for education, planning and resource allocation. General population should also be made aware about the ways to reduce harm to our environment. Intergovernmental efforts should be made to check climate change, avoid deforestation and use alternative sources of energy like solar energy instead of petroleum products. Ultimately, as embedded in its definition, ecosystem is a community, and unless all people in community put efforts to conserve it, no amount of individual effort can suffice. Therefore, a close teamwork between scientists, public health professionals and administrators is needed for integrated vertical and horizontal planning.

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