Climate Change and Population Health

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Abstract

Human health and climate have a deep rooted co-existence since the inception of mankind on mother earth. An understanding between the two has been established since times immemorial with the great work of scientists and scholars. Human health and disease have made great strides in the present day world, while more emphasis on causal relationships of various diseases with various factors both internal as well as external is being studied. No conclusive data or little evidence suggesting climate change as responsible in the changing patterns of disease is available. But extreme changes in temperatures like cold and heat waves coupled with the increased or decreased precipitation levels causing famines and floods and the presence of aeroallergens with increased air pollution levels cause a brunt on human health on an individual level. Vector borne diseases are directly affected with the change in temperature and precipitation levels. Water related diseases arising due to poor quality, quantity of water with minimal personal hygiene share a complex association. Loss of human lives, health infrastructure, and public properties by the calamities like storms, cyclones, hurricanes which we witnessed in Asia, America in recent times are a forecast for the future world to tackle this situation now or never. On the other hand, vulnerable population of low to middle income countries suffer the greatest brunt of climate change related health burden. Thus mitigation of health related impact of climate change should be tailor made keeping in view the regional health threats. Effective strategies need to be devised at all levels of healthcare delivery system.

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8.1 Introduction

Change is the essence of life and is inevitable. Change is what made life possible on this mother Earth. Change can be seen both in positive as well as negative directions. Climate change has evolved from times immemorial. It brought so many boons and banes in every aspect of life, be it the extinction of some species or origin of others. It led mankind for betterment from ice age towards civilization. Health of the population too has been affected with this change in climate. Climate change broadly affects the environmental and social dimensions of health and well-being of people in particular and populations in general. However, in last few decades the changes have been quite remarkable owing to changing population size and extent of economic activities, which has started creating imbalance in the ecosystem per se.

It is very important to understand what has led to climate change. The surface temperature of earth is a result of combination of natural processes that take place inside and around the earth's atmosphere which include solar activity, volcanic activity, dust and aerosol in the atmosphere, reflection of some energy back by clouds, ice and snow. Far more important than all these is greenhouse gases (GHGs) which are produced as a result of human activity (anthropogenic greenhouse gases). The greenhouse gases trap solar energy and create a blanket for earth which prevents heat loss from earth's surface. This action of greenhouse gases can be exemplified by comparing it with the effect observed inside a car parked in sun with window panes up. Among greenhouse gases, carbon dioxide (CO_2) is the most abundant gas. In nature, the concentration of carbon dioxide is maintained by going through atmosphere to oceans and from oceans it gets impounded in rocks which ultimately reach back to atmosphere after being thrown out by volcanic eruption. What is so astonishing is the fact that over the last half of the century, there has been remarkable escalation of atmospheric CO_2 as a result of human activities which include overuse of energy sources and deforestation. The concentration of CO_2 in the atmosphere has risen gradually from about 280 parts per million (ppm) in pre-industrial times to 400 ppm in the year 2014. In addition to carbon dioxide, methane and nitrous oxide are two other shorter-lived but more potent greenhouse whose concentration has also increased acutely in the last 50 years (Woodward and Macmillan 2015).

Though the reported rise in global temperature has been 0.6 °C predominantly from 1970 onwards, the Intergovernmental panel on Climate change (IPCC) have forecasted that the atmospheric carbon dioxide will double its pre-industrial level between the years 2050 and 2100, which will shift the global temperature upwards by 2–2.5 °C by the end of this century (Soloman et al. 2007).

Environmental and Social Scientists see climate change detrimental to mother Earth, so does health care providers. Hippocrates, known as father of Medicine made

valuable contribution in our understanding about role of environmental determinants on health of population. The Aphorisms of Hippocrates is direct evidence to it, which he has penned down in the introductory portion of treatise on "Airs, Waters, Places" and this is considered as the first ground work knowledge on the environmental health determinants. It begins as saying "*Whoever would study medicine aright must learn of the following subjects. Firstly, he must consider the effect of each season of the year and the differences between them. Secondly, he must study the warm and the cold winds, both those that are common to every country and those peculiar to a particular locality. Lastly, the effect of water on the health must not be forgotten. When, therefore, a physician comes to a district previously unknown to him, he should consider both its situation and its aspect to the winds. Similarly, the nature of the water supply must be considered. Then think of the soil, whether it be bare and waterless or thickly covered with vegetation and well watered, whether in a hollow and stifling, or exposed and cold. Lastly consider the life of the inhabitants themselves, are they heavy drinkers and eaters and consequently unable to stand fatigue or, being fond of work and exercise, eat wisely but drink sparely*"(Lloyd 1978). It is important to appreciate the observations made more than 2000 years ago about various components of environment including climate, and their effect on human health.

If we go back in history, human population has been witness to the extreme changes in temperature which led to flooding in 1980 in Sudan with consequent diarrheal disease outbreak. Similarly, in 1998 floods in one of the states of India led to massive Cholera Epidemic due to 01Eltor, Ogawa. Outbreak of Leptospirosis in Brazil (1983, 1988 and 1996), India (1999), and Thailand (2000) was also attributed to climate change (WHO 2002). In Burma (2008), Cyclone Nargis caused approximately 138,000 deaths and US $10 billion damage; in the USA, Hurricane Katrina in 2005 was responsible for nearly thousand deaths (Fritz et al. 2009) (Brunkard et al. 2008). Other example like occurrence of acute illness that happened after eating sea-foods contaminated with *Vibrio parahaemolyticus* in North America which was attributed to rising temperature of the farm beyond a critical level that was considered sensitive for the survival of organism. Being a temperature sensitive organism, rising temperature favored its survival in local shell-fish which was consumed by the local populace (McLaughlin et al. 2005). Researchers have pointed out direct connection of climate change to the human deaths. Be it the wild fires in the USA which ravaged into larger swaths of its country land or the 2014 floods in Kashmir, India which marooned the Valley for more than a month. In 2003 European Heat wave resulted in nearly 70,000 deaths in 12 countries and climate change increased the heat related deaths by 70% in Paris and 20% in London. Hot days are common and summers tend to be longer in some regions where there was a reverse trend.

In order to understand the population health and impact of any event or risk factor on health one should have methods to measure it. Traditionally health and disease have been measured in terms of mortality rates. However, the major drawback of this indicator is that it ignores the parameters that compromise the function and quality of life without causing end of life event like accidents causing disability or mental ill health. Hence a new metric, Disability adjusted life years (DALYs) which are a

composite index of quantifying years of life lost due to premature death and years lived with disability were introduced (WHO 2017).

Global Climate change is being incriminated for about 1,50,000 deaths and 5.5 million DALYs lost per year with highest burden of climate change per million populations in the regions of Sub-Saharan Africa despite the fact that their contribution towards global climate change has been very minimal. Recent estimates given by World Health Organization reveal that globally climate change will cause 2,50,000 additional deaths per year between 2030 and 2050 and direct financial loss to health is estimated to be USD 2 to 4 billion per year by 2030 (Haines and Berlin 2014; WHO 2018).

The health impacts of climate change differ with population because of variation in resources which determine their vulnerability. It has been observed that overcrowding, food insecurity, local environmental degradation, conflicts, socio economic and ecological conditions play a crucial role in determining the impact of climate change. Hence the climate change does not only act as a risk multiplier but itself contributes to the risk for ecosystem (Woodward and Macmillan 2015).

Climate Change and population health are indispensible to each other. Climate Change can have direct and indirect effects on population health which depends upon various demographic groups having an altogether change in their health patterns than others (Table 8.1). Today we can see climate change as a public health emergency and can be predicted for future generations too. Direct changes are an outcome of extreme weather and indirect changes are secondary to changes in the range of vector population. Events like increased frequency, duration and intensity of heat waves, draughts, floods, storms, wild fires which mankind is witness to today have led to death, injury, disease and displacement of thousands of people. In this chapter, impact of climate change on population health will be considered as a consequence of following alterations (McMichael et al. 1996): (Table 8.1)

(a) Direct Changes

- Exposure to thermal extremes
- Intensity of other extreme weather events

(b) Indirect Changes

- Effect on vector activity
- Altered ecology of waterborne and food-borne agents
- Alteration in food productivity
- Population displacement

(c) Direct and Indirect Effects of Increased Ultraviolet Levels (McMichael et al. 1996)

Table 8.1 Direct and indirect pathways of climate change and their influence on human health

I. Temperature and weather changes	Consequence of climate change	Health outcome
	Direct pathway	
	Exposure to thermal exposure	Heat and cold related illness Death
	Alteration in other weather events	Death Injuries Psychological disorders Damage to public health infrastructure
	Indirect pathway	
	Effect on range and activity of vectors	↓↑incidence of vector borne disease
	Alteration in infective agents	↓↑incidence of diarrheal disease
	Alteration in crop production	Malnutrition Impairment of child growth and development
	Rise in sea level→ Population displacement Damage to infrastructure	↑ Infectious disease risk ↑Psychological disorder
	Biological impact of air pollution Pollens and spores	Respiratory disorders Deaths Asthma and allergic disorders
	Effect on economy, infrastructure and resource supply→sociodemographic dislocation	↑ Mental ill health ↑ Nutritional impairment ↑ Infectious disease Civil strife
	Direct pathway	
II. Stratospheric ozone depletion		Skin cancer Cataract Immune suppression → ↑susceptibility to infections
	Indirect pathway	
	Impaired productivity of agriculture → ↓food production → hunger	Malnutrition Impaired growth and development
	Impaired productivity of aquatic systems → ↓ population of predators of insect vectors	Vector borne infectious disease

8.2 Consequences of Climate change

8.2.1 Exposure to Thermal Extremes and Other Weather Events

Health impact of thermal extremes encompasses effect of both hot and cold environmental temperature which includes heat stress, heat exhaustion, and heat stroke. The most vulnerable population groups like children, elderly, women, and people who move out to earn livelihood and work in external environmental conditions for at least 6–8 h are at greater risk of facing heat related morbidity and mortality. Excessive daily heat exposures decrease work efficiency and interfere with daily activities. The impact of extremes of cold shows marked seasonal variation with 10–25% excess cold related death rate in winter season. As compared to heat related mortality which are mostly attributed to direct impact of heat in the form of heat exhaustion and heat stroke, cold related deaths are mostly due to exacerbation of underlying morbidity like cardiovascular disease or chronic obstructive pulmonary disease (COPD). The increased mortality has been attributed to cold induced tendency for blood to clot (Keatinge et al. 1989).

Increased precipitation levels have led to increasing entry of human and animals into waterways and drinking sources, thus there will be an increase in the frequency and magnitude of common disasters like flood, storm, and drought. These increase the chances of injuries as well as disease outbreak (Infectious), mental trauma, and reduction of work productivity (McMichael et al. 1996).

8.2.2 Biological Impact of Air Pollution, Pollens, and Spores

It has been hypothesized that due to increased atmospheric temperature the production of secondary air pollutants is accelerated. On inhalations of such chemicals the respiratory cells are acutely affected thereby impairing lung function (Romieu et al. 1990). Seasonal allergic disorders like hay fever and asthma are also impacted due to alteration in the production of plant aeroallergens which are considered to be sensitive to climate change (Emberlin 1994).

8.2.3 Effect Due to Change in Range and Activity of Vectors

The indirect effects of change in global climatic conditions are widespread and diverse. Human health effects are interactive and complex with the changing climatic conditions of a region which is primarily linked to alteration in various biological organisms and the processes linked with their transmission to human host. Temperature, humidity, precipitation and wind, influence biting rate, egg production, vector distribution, and passive dispersal of flying insects and consequent survival benefit to the affected vector species. Dispersion of insect vectors could possibly pave way for creation of new species which might pave way to new hosts previously immune to the parent vector. Population displacement as will be

observed during floods and droughts would expose human population to vectors which were otherwise maintaining their lifecycle in wildlife and did not cause any significant disease in humans. At the same time one needs to consider existing vector population dynamics before making predictions about the impact of climate change on distribution of vector borne disease (McMichael et al. 1996).

Malaria affects about 50% of the world's population which is projected to increase to 60% and with more frequent epidemics (Martin and Lefebure 1995). In 2017 local transmission of malaria and Chikungunya was reported in Italy, an area declared malaria free in 1970 by WHO (CDC 2017a). Exact cause was uncertain but it showed a vulnerability to the changes presented by climate change. Scenario based modeling studies have predicted increase in prevalence of malaria in response to rise to global mean temperature in many parts of the world by the year 2100. The climate change will have potential effect in the transmission of malarial parasite favoring its spread by both latitude and longitude in tropical areas. Areas which previously exhibited stable transmission of *Plasmodium falciparum* in particular will become more unstable with high mortality and morbidity among the newly exposed population (CDC 2017b).

Dengue, like malaria is transmitted by vector mosquito (*Aedes aegypti and A. albopictus*) and exhibits similar dynamics with temperature being the key predictor for transmission of infection. Diseases like tick borne encephalitis and Lyme disease also have been found to be influenced by climate change though the exact mechanism of how climate change will affect pattern of transmission of these infection is uncertain. However, it has been said that increase in temperature to a certain level and precipitation are more hospitable for fleas and ticks also. On the one hand, high temperature is suitable for multiplication of tick population and on the other side, it causes reduction in predators of deer mice (McMichael et al. 1996).

Arboviral diseases, most of which are mosquito borne are predicted to be changed throughout the globe due to the effect of changing climate. Resurgence of one of the worst outbreak of West Nile fever in 2012 in America has been attributed to change in climatic conditions. Similarly, Ross River virus disease, a major Australian arboviral infection is greatly influenced by alteration in rainfall pattern (Young et al. 2014).

Onchocerciasis, transmitted by blackflies, occurring mostly in Africa is also a climate sensitive vector. Simulation studies have predicted that blackfly population could increase by 25% which can increase the possibility of risk of onchocerciasis in previously naïve population as these vectors move to newer areas creating new habitats. Climate change can make animal reservoirs and hosts to migrate from one area to another thus bringing them closer to each other and increasing exposure to populations with lower immune status (Hales et al. 1999) (McMichael et al. 1996).

Change in climatic conditions would also affect the life cycle of Schistosoma which enter human host by penetrating through the skin. It does so through two mechanisms. Firstly, in response to hot climate there will be likely spreading out of irrigation system with subsequent increase in host snail population, secondly, high temperature would arbitrate transmission of infective stage throughout the year which would otherwise lose their infectivity in winter seasons.

Leptospirosis, a spirochaetal disease transmitted through rodents could also increase due to expected increase in rodent population in warmer temperate areas. Similarly, rabies virus infection which is transmitted through bite of blood sucking bats in America is anticipated to be increased as climate changes and brings more favorable temperature for this biting mammal.

Population of pests like flies and cockroaches which transmit diseases by carrying infectious agent on their body or proboscis may increase because of higher temperature making difficult to control these pests and the diseases transmitted by them (McMichael et al. 1996).

8.2.4 Effect of Alteration in Infective Agents

Increase in land temperature will impact the pathogenic proliferation and also affect the rate of transmission of various infectious agents which are primarily transmitted through direct route (food, water). With expected scarcity of clean and safe water, the incidence of diarrheal disease caused by *Salmonella*, *Shigella, Campylobacter, Rotavirus,* and protozoans (*Giardia lamblia*, *Entamoeba histolytica*) are likely to increase. Diarrheal diseases exhibit seasonal trends intensifying during summer season and is compounded by poverty, population displacement, overcrowding, poor sanitation, and hygiene. These conditions will tend to exacerbate the occurrence of diarrheal diseases caused by *Vibrio cholera* in particular which is a climate sensitive infectious disease agent. Disease models used to study transmission of Cholera have shown that alteration in temperature and precipitation with increase in sea levels is expected to increase frequency of cholera infection in future. Similarly, *Salmonella* causing food poisoning proliferate rapidly at higher temperature and change in eating pattern (consuming foods frequently contaminated with *Salmonella*) due to change in outdoor temperatures might also affect exposure (D'Souza et al. 2004).

Looking at the current scenario of some infectious diseases like recent shift in Malaria in Sub-Saharan Africa, tick borne encephalitis in Sweden and Schistosomiasis in Eastern China due to change in regional temperature and alteration in seasonal and inter-annual pattern of certain enteric pathogens like Cholera and Salmonella is a stronger indicator reflecting impact of climate change on the dynamics of infectious disease (Woodward and Macmillan 2015).

8.2.5 Effect of Alteration in Crop Production

Climatic change threatens mankind with food shortage as crop yields are going to be directly affected by droughts and famines thus leading to food shortage and poverty. However, populations which are already food deficit or are directly related to the food production process, even a slight reduction in the yield predispose them to malnutrition (under nutrition). Crop yields are in addition to temperature sensitive to change in soil moisture and activity of pollinating insects. Though scientists have

foreseen initial increased production of certain crop variety in response to increased carbon dioxide levels and soil moisture, however, with altered precipitation flooding and soil erosion will be precipitated which will have strong negative influence. The world is already suffering from under nutrition with regional disparities, be it the vast deserts of Africa or Central America where scores of children are facing different forms of undernourishment in the form of wasting, stunting, and underweight. In India, empowered action group states which are classified on the basis of poor health indicators (Madhya Pradesh, Orissa, Bihar, Uttar Pradesh, West Bengal, and Rajasthan) are badly hit by under nutrition. The under nutrition leads to impaired childhood development which occurs in first 10 crucial years of life thus effecting all stages of an individual's development. It has been estimated that people who would be at extra risk of hunger due to alteration in climate by 2060 would be 5–35% more than is expected in the absence of climate change (Woodward and Macmillan 2015).

8.2.6 Effect of Extreme Weather Events

Extreme weather events like floods, droughts, forest fires, and landslides have increased in frequency over past few decades with tropical Asia and tropical America considered being high risk zones. Impact of extreme weather condition on population health is greatly influenced by social, economic, and political factors (Fig. 8.1). For example, impoverished populations who have limited accessibility to health services are at higher risk of facing health inequality when faced with consequences of extreme weather events like floods. Extreme weather events are likely to induce population migration on large scale as is observed following floods

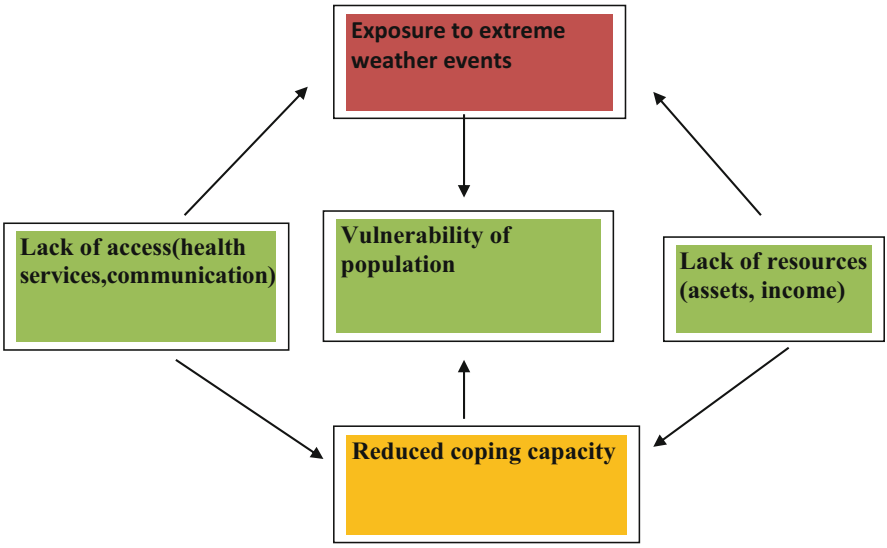

Fig. 8.1 Schematic illustration depicting factors determining vulnerability of population

which would affect the risk of infectious disease outbreaks. Heat waves coupled with air pollution lead to higher burden of respiratory diseases as well as non-communicable diseases. Burning of fossil fuels with higher temperatures exacerbates chronic lung conditions like asthma and allergic disorders. The clinical condition of patients with heart disease, diabetes deteriorates if exposed to excessive heat levels. The mental well-being of a person depends directly upon the economic status. With large spells of drought conditions farmers out of frustration attempt suicides, this is a growing concern in various states of India where farmer deaths are occurring day in and day out (McMichael et al. 1996; Woodward and Macmillan 2015).

8.2.7 Effect of Stratospheric Ozone Depletion

Climate change and stratospheric ozone depletion are closely related entities. With the accumulation of GHGs, there is enhanced effect of radioactive elements on climate and destruction of ozone by chlorine radicals increases ultraviolet radiation entry into lower atmosphere. In nature, stratospheric ozone is responsible for absorption of enormous amount of incoming solar radiation which is a mixture of visible, infrared, and ultraviolet rays. Ultraviolet rays are further subdivided into ultraviolet A, ultraviolet B, and ultraviolet C rays. Stratospheric ozone absorbs all of UV-C radiations, nearly three forth UV-B but only a small amount of UV-A radiation. In addition to ozone, some amount of ultraviolet rays is absorbed in the troposphere layer of the earth's atmosphere by suspended particulate matter, dust, and clouds. Recent modeling estimates show concordance with the observations made in certain countries regarding increased ground levels of UVR in relation to ozone depletion. The percentage increase in UVR reaching the earth varies exponentially with the percentage decline in stratospheric ozone depletion. The increase in ground level of ultraviolet radiation has a varying impact on health of human beings which has both positive and negative consequences. For instance, UV-B is needed by human body to synthesize vitamin D which is an essential fat soluble vitamin and has a role in maintaining calcium level in the human body. However, sustained exposure to UV radiations has been found to be harmful for all forms of life on earth (Quaite et al. 1992) (Blaustein et al. 1994). At molecular level, both UV-B and UV-C induce direct damage to DNA which exhibits dose–response relationship. These radiations have been implicated in the causation of cutaneous malignant melanoma and non-melanocytic skin cancer (Fig. 8.2). Non-melanotic skin cancers are of two types: basal cell carcinoma and squamous cell carcinoma. Incidence of skin cancer is increasing rapidly among fair-skinned populations and who spend most of the time in outdoor activities. The incidence of these cancers has doubled over the past 25 years in Canada. It has been estimated that at least 80% of all melanomas are caused by exposure to sunlight, particularly in highly exposed populations with fair skin, like Australians of Caucasian origin. Ultraviolet radiations have been classified as Group 2A carcinogen by International agency

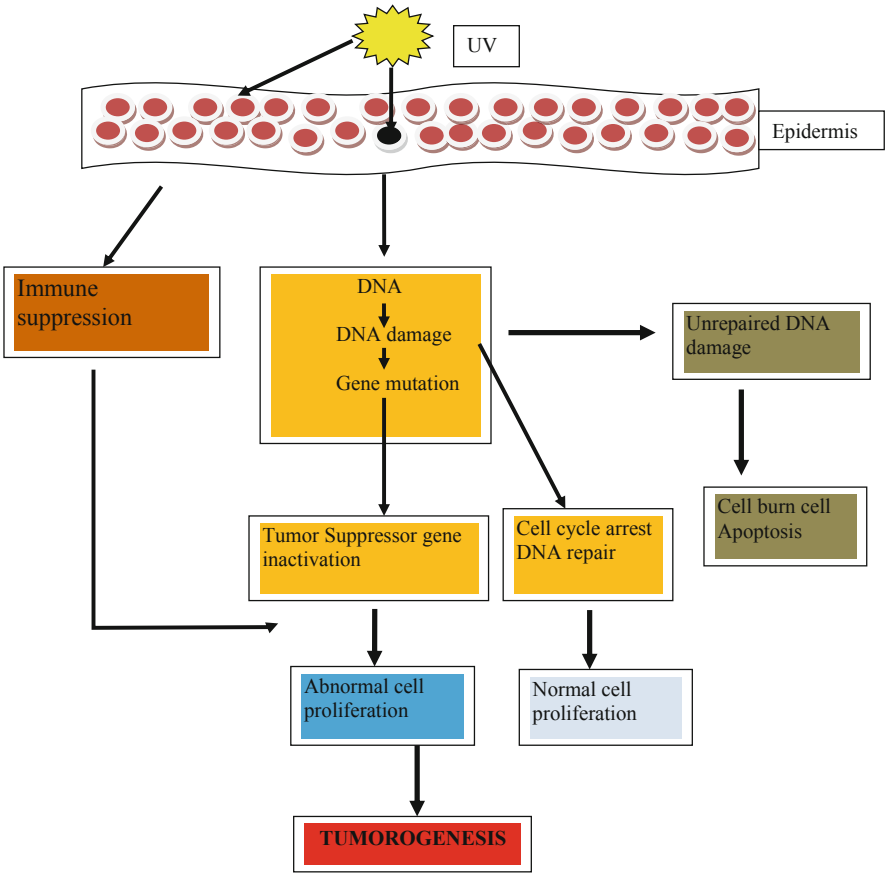

Fig. 8.2 Pathway depicting mechanism of non-melanoma skin cancer by ultraviolet radiation. (Source: IARC Monographs on the evaluation of carcinogenic risks to humans 1992)

for research on Cancers (IARC) which is for being a probable carcinogen to humans (IARC 1992).

In addition to this effect, sufficient amount of evidence exists on the role of ultraviolet radiations in the suppression of cell mediated immunity and ocular effects (photoconjunctivitis and acute photokeratitis) (McMichael et al. 1996).

8.3 Future Trends

Mathematical modeling, an important epidemiological tool is very commonly used framework not only to understand the complex biological or population-based process but also to develop a more simple and easily understandable sequence of events and future projection and consequent impact which helps to define processes

clearly and identify the most important components of a system. It is used to explain the real world problem in terms of mathematical equations. It is employed in many areas of public health research and practice. For example, this approach has been widely used to understand infectious disease epidemiology and is now being used by epidemiologists to elucidate the complex phenomenon of climate change as well as to depict future trend and consequent impact of climate change of ecosystem (Woodward and Macmillan 2015).

In addition to current estimates, Global Burden of Disease project 2002 included estimates of deaths and disability adjusted life years attributable to climate change in 2030 (Fig. 8.3). In the case of diarrheal disease, it was assumed that the relation between temperature and incidence would not change, and that vulnerability to warming-related diarrheal disease would also remain as it is currently. Based on outputs from the MARA (Mapping Malaria Risk in Africa) project it has been projected that within 50 years, malaria could be established in the densely populated and presently malaria-free highlands of Zimbabwe. Similarly, in China, it has been estimated that additional 8% of land area will become suitable for snail that harbor the parasite responsible for Schistosomiasis (Zhou and Yang 2008). Additionally, a study modeled the current relation between mean annual temperature and hospital admissions for nephrolithiasis (stones in the urinary tract) in the USA. Based on future projections on mean annual temperatures the potential increase in hospital admissions and associated costs was calculated. Nearly two million additional lifetime cases of nephrolithiasis have been projected to attribute to climate (Brikowski et al. 2008).

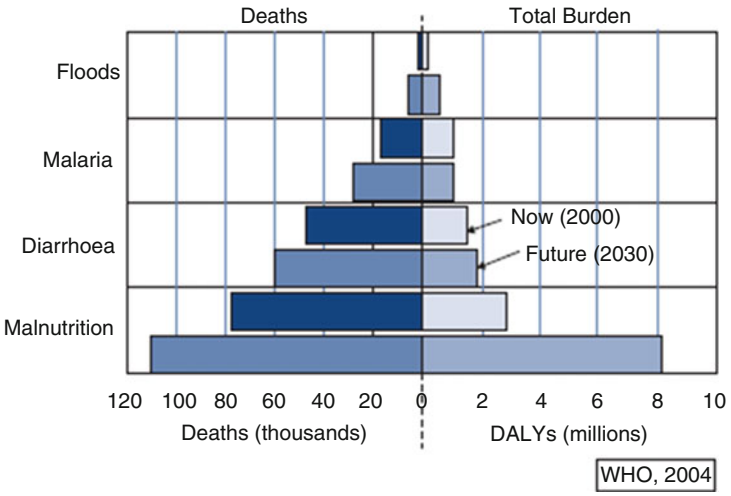

Fig. 8.3 Deaths and DALYs attributable to Climate Change, 2000 and 2030 Selected conditions in developing countries. Source: data from World Health Organization, The Global Burden of Disease 2004 Update, World Health Organization, Geneva, Switzerland, Copyright© (World Health Organization 2008)

With expected increase in world population from about 7 billion presently to around 9.5 billion by 2050, and projected decline in mortality which is more pronounced in high income group countries it has been estimated that the overall burden of disease will be reduced by about 30% by 2030 (WHO 2008). With continued socioeconomic development, the vulnerability of populations to climate change is expected to continue due to increased greenhouse emissions. With country like India which is going through enormous social and economic transition has not made much progress in health indicators (Subramanyam et al. 2011).

Although projection estimates created by mathematical modeling is far from complete, however it provides a basis for likely impact of climate change thereby enabling nations to prepare and respond in time.

8.4 Strategies to Minimize the Health Risk

As described in the earlier section, climate change acts as a risk multiplier with populations having poor health indicators being the most sufferers. This was also reflected by World Bank, in its 2010 World Development Report considering baseline health status as the single most important determinant of both future losses, and the cost of adaptation (World Bank 2009). Hence it becomes imperative to take immediate action to combat ill effects of global climate change to ensure protection and promotion of health of the people with focused approach towards vulnerable population. As we know climate change has more adverse effects than benefits to population health, but the health benefits are overshadowed by far impacting adverse outcomes as being observed presently and may get worse in future. Climate change mitigation strategies should be devised to reduce its ill impact on population health for better future as well as present. With life expectancy to grow further in low income countries, lively environment is needed for future generation to combat the harmful effects of global climate change. To achieve this, the existing health systems need to be strengthened for concrete coping capacity. As observed climate change will act primarily by intensifying existing loopholes in the socio-ecological environment of people, hence the existing health sectors have to develop adaptive strategy and provide strong foundation to safeguard health and reduce health impact of climate change. The strategies need to extend across different allied sectors and should include the following components:

1. Health risk communication to population with special focuses on susceptible ones.
2. Establishment of event specific early warning signals.
3. Better urban planning, climate-proof housing and improved farming practices.
4. Disaster preparedness to cope up with increase in acute demands on health system.
5. Expanded infectious disease control programmes (development of candidate vaccines and stock piling, integrated vector management, case identification and treatment).

6. Better disease and risk factor surveillance network.
7. Development of appropriate Manpower (recruitment, training for capacity building).

Risk communication involves the process of identifying the key message chosen by experts in the field which is relevant and beneficial to the public. Effective risk communication is quite essential in managing risk and enables people to make right decision at right time. This will prevent damage and injuries due to impending risk which is climate change in this context and encourage people to safeguard their life. Risk communication plays pivotal role in risk management.

Surveillance plays key role in protection and promotion of environmental health. It involves systemic collection, analysis, and interpretation of data specific to the health event in a population and application of that information in the prevention and control of that factor. The ultimate aim of surveillance (disease, risk factor) is protection and promotion of health of the population. Setting up of strong risk factor and disease surveillance network will help in monitoring the trends in illness due to specific exposure (for example, exposure to extreme heat and heat stroke), and identifying opportunities to prevent and control effects of climate change.

Another key area for mitigation strategies is to identify and protect the susceptible. Susceptible population poses special challenge for any intervention. It is of utmost importance to identify the susceptible in the population because their needs are different due to enhanced vulnerability to any health risk. This population includes children, pregnant women, people who live in poverty, people with chronic diseases and those who work in high risk areas (extremes of temperature). Children by virtue of their poor judgment cannot avoid exposure to environmental pollutants in and around the home and need adult supervision. Further children in poor resource settings are further exposed to poor drinking water, overcrowding, lack of sanitation, burning of fossil fuels within the households which has an additive to their risk (Woodward and Macmillan 2015).

In addition to adaption strategy it is equally pertinent to initiate mitigation strategy to reduce the emission of greenhouse gases with utmost priority. Limiting global warming to 2 °C by the end of the century has been the consensus target for policymakers and scientists across the globe. Since energy sector emissions contribute to more than one-third greenhouse gas emissions currently, low carbon source in the form of nuclear and other renewable energy needs to become main source of energy supply by the end of year 2050. This will not only reduce impact of greenhouse gases and air pollution but will have an additional benefit of ensuring energy security.

At household level use of clean fossil fuel, biogas, or ethanol for cooking purpose and space heating will reduce emission of black carbon emission which is a short lived climate pollutant thereby reducing health risks.

Transport sector, despite being the fastest growing sector in terms of energy demand a substantial scope exists to reduce the energy demand by 40% and consequent CO_2 emissions by 15–40% by 2050. Transport mitigation measures include modal shift of motorized traffic to dedicated bus rapid transit (BRT),

complemented by dedicated walking and cycling infrastructure. Compact urban planning and neighborhoods with safe walking/cycling routes to reduce trip length and carbon intensity of journeys and improved vehicle and engine efficiencies along with uptake of low carbon fuel sources will achieve population health benefits.

Mitigation measures to reduce building emissions which has been projected to increase by 50–150% by year 2050 should include climate-adapted building design to reduce the need for heating in temperate countries and air conditioning in warm countries. Secondly, selective use of day lighting and natural ventilation can be adapted to reduce cooling requirements. Low carbon heating and cooling systems, and energy efficient building appliances should be used to improve thermal comfort.

With increasing burden of non-communicable diseases like diabetes mellitus, cardiovascular diseases, cancers, and chronic respiratory diseases, the health systems capacity to respond to staggering demand for complex health care services that increasingly rely on diagnostic and treatment options that are highly technology dependent, is posing great challenge. Hence it is important to devise mitigation measures at the health system level in order to reduce the carbon-footprint without compromising on patient care. Even though there is sparse evidence available on greenhouse gas emissions by the health system. However, some estimates from certain health sectors of UK and USA suggest that 3–8% of GHG emissions comes from the health sector of these countries. As health sector has a central role in protecting and promoting population health, it has to play a key role and lead by example in implementing mitigation measures in order to avoid contributing to the devastating health impacts of climate change. This can be achieved by adopting clean and more reliable energy sources and climate resilient infrastructure. Building of Climate smart health facilities especially in high income settings can save 30–50% of energy in the long run. This can be achieved through modification of parameters of physical environment like use of mixed mode and natural alone ventilations, use of passive cooling and heating through landscaping and other building modifications procurement of efficient and sustainable health care commodities like cleaning agents and other medical supplies and pharmaceuticals will not only reduce greenhouse gas emissions but will also reduce occupational hazards.

Now, it is for all countries to devise their national policies wherein such measures are integrated. It needs lot of groundwork as the countries have to go for cost benefit analysis as well as health impact assessment of mitigation measures in their own settings for rational policymaking. The successful deployment of mitigation policies needs strong political commitment.

Another key area of concern is the need to ensure that policy measures also influence behavioral changes at the individual level which is conductive to more sustainable living which include shifting from over consumptions of foods which form risk factors for major non-communicable diseases like diabetes, cardiovascular diseases, obesity, and certain cancers like colorectal and breast cancer (WHO 2015).

8.5 What is Being Done at Country and International Level?

The United Nations Framework Convention on Climate Change is a central forum for intergovernmental negotiations on climate change. Under the Convention the member states have committed to "employ appropriate methods, for example impact assessment . . . with a view to minimizing adverse effects on the economy, on public health and on the quality of the environment, to projects or measures undertaken by them to mitigate or adapt to climate change" (WHO 2015).

At United Nations Climate Change summit (UNCC) 2018, the country heads expressed their pledge to unite the world to agree on the next steps towards achieving climate goals. A key part of the process was to limit global warming to 1.5 °C which requires concerted efforts by all sections of the society. Multiple efforts are being taken at international forum to combat global effects of climate change. The countries exchange their ideas and share their experiences and steps taken at national and regional levels and express their commitment towards mother earth which is not only home to the current generation but the future generations to come. The Katowice climate package is recent in this path wherein more than 20,000 individuals participated which included local people, heads of state, media representatives, and members of various organizations including United Nations who are working towards combating climate change. They provided operational framework for climate action and guidance for countries to track greenhouse gas emissions and evaluating efforts at the national and international level. The framework sets year 2050 for net zero emission of GHGs. The countries are encouraged to continue their efforts towards combating climate change as the past emissions would continue to change the climate which will have adverse effect on underprivileged and vulnerable communities of the world. To address loss and damage due to climate change, the countries are encouraged to report on efforts to enhance actions that overcome such effects and this will be assessed every 5 years at the time of global stocktake of progress. In addition, every year, regional climate week takes place at Nairobi, Singapore, and Montevideo to inspire countries to take greater action towards reducing their greenhouse gas emissions.

Through Clean Development mechanism, under Kyoto Protocol, in which 140 countries which include 36 least developed countries, contributed towards reduction or avoidance of 2 billion tonnes of CO_2 through sales of credits known as certified emission reductions (CERs) (which represent one tonne of carbon dioxide (CO_2) equivalent). This was achieved by planting 152 million trees, use of natural resources in 25% of projects, installation of one million efficient cook stoves. In order to achieve long-term low greenhouse gas emission, development strategies have been devised globally with support from various organizations and local governments.

Involvement of communities, through various platforms where they can share their views, ideas and efforts towards response to the challenges posed by climate change, has opened further space for exchange of ideas and engagement of people from all sections of the communities (United Nations 2018).

Human race has always adapted socially, culturally to the ecosystem in which they lived. Migration has been one of the primary steps in case where climate change made impossible for man to live in; but keeping in view today's world scenario increasing urban settlements for economic or social reasons one will find hard to migrate. The strategies thus devised should be made keeping in view the regional, cultural, social determinants. Carbon dioxide and other greenhouse gas emission is a prime concern where global economies fight with each other on that account. The Paris agreement in 2016 set the targets for greenhouse gas emissions. To solve this situation, they have to take a call and find long-lasting solutions for its mitigation otherwise the world will not be an environment of sustenance in next 100 years for man to live and endure.

Reaching out to those people who are in absolute poverty and depend upon fossil fuels as a primary source of household energy will have to be given a better option in the form of renewable sources of energy like solar energy.

A disaster management policy with their implementation is the need of the day especially in low income countries where disasters take a heavy toll on the already scarce resources. Buildings should be designed in such a manner that produces a healthy indoor environment for living as well as working in extreme temperatures and yet reduces the energy demand. As vector borne diseases are influenced by climate change, preventive programmes focusing on development of effective vaccines, mosquito control, food hygiene, sanitation and nutritional supplementation to vulnerable population need to be effectively devised. We can responsibly take action with sensible steps towards safeguarding health of the population. Energy efficient public transport and use of bicycles and walking for short daily trips by the masses will lessen the use of energy. Better land use planning for building purposes can reduce flooding, restriction of building permissions in flood prone areas with relocating areas which experience frequent flooding.

Beyond this, policy decision at national and international level is immensely critical which will in a longer time horizon help in averting climate change. The healthcare providers have opportunity as well as responsibility to make this happen at individual level which will ultimately culminate into an immense change at global level.

References

Blaustein AR, Hoffman PD, Hokit DG et al (1994) UV repair and resistance to solar UV-B in amphibian eggs: a link to population declines. Proc Natl Acad Sci U S A 91(5):1791–1795. https://doi.org/10.1073/pnas.91.5.1791

Brikowski TH, Lotan Y, Pearle MS (2008) Climate related increase in the prevalence of urolithiasis in the United States. Proc Natl Acad Sci U S A 105(28):9841–9846. https://doi.org/10.1073/pnas.0709652105

Brunkard J, Namulanda G, Ratard R (2008) Hurricane Katrina deaths, Louisiana, 2005. Disaster Med Public Health Prep 2(4):215–223

Centers for Disease Control and Prevention (2017a) Malaria in italy. https://www.cdc.gov/malaria/new_info/2017/Italy_2017.html. Accessed 11 Sept 2019

Centers for Disease Control and Prevention (2017b) Chikungunya in Italy. https://wwwnccdcgov/travel/notices/watch/chikungunya-italy. Accessed 11 Sept 2019
D'Souza RM, Becker NG, Hall G et al (2004) Does ambient temperature affect foodborne disease? Epidemiology 15(1):86–89
Emberlin J (1994) The effect of patterns in climate and pollen abundance on allergy. Allergy 49:15–20
Fritz HM, Blount CD, Thwin S, Thu MK, Chan N (2009) Cyclone Nargis storm surge in Myanmar. Nat Geosci 2(7):448–449
Haines A, Berlin A (2014) Global health. In: Manson's tropical diseases, 23rd edn. Elsevier, Amsterdam, pp 9–15
Hales S, Weinstein P, Sovares Y, Woodward A (1999) El Nino & the dynamics of vector borne disease transmission. Environ Health Perspect 107(2):99–102
International Agency for Research on Cancers, Ultraviolet and solar radiation (1992) IARC monographs on the evaluation of carcinogenic risks to humans. IARC Press Lyon, France
Keatinge WR, Coleshaw SRK, Holmes J (1989) Changes in seasonal mortalities with improvement in home heating in England and Wales from 1963–1984. Int J Biometeorol 33:71–76
Lloyd GER (1978) Hippocratic writings. In: Harmondsworth. Penguin classics, London
Martin PH, Lefebure M (1995) Malaria and climate: sensitivity of malaria potential transmission to climate. Ambio 24(4):200–207
McLaughlin J, Paola D, Bopp C (2005) Outbreak of Vibrio parahaemolyticus gastroenteritis associated with Alaskan oysters. N Engl J Med 353(14):1463–1470
McMichael AJ, Haines A, Slooff R et al (1996) Climate change and human health. An assessment prepared by task group of World Health Organization, World Meteorological Organization and United Nations Environment Programme. World Health Organisation, Geneva
Quaite FE, Sutherland BM, Sutherland JC (1992) Action spectrum for DNA damage in alfa alfa lowers predicted impact of ozone depletion. Nature 358:576–578
Romieu I, Weitzenfeld H, Finkelman J (1990) Urban air pollution in Latin America and Caribbean health perspectives. World Health Stat Q 23(2):153–167
Solomon S, Qin D, Manning M, Marquis M et al (2007) Climate change: the physical science basis. Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. Summary for policymakers. Cambridge University Press, New York
Subramanyam MA, Kawachi I, Berkman LF et al (2011) Is economic growth associated with reduction in child undernutrition in India ? PLoS Med 8(3):e1000424
Technical Briefing for the World Health Organisation (2015) Conference on Health and Climate. Promoting health while mitigating climate change. 27–29 August, Geneva. https://www.who.int/globalchange/publications/briefing-health-mitigating/en/. Accessed 15 Nov 2019
United Nations Framework Convention on Climate Change (2018) United Nations Climate change Annual report. http://unfccc.int/news/un-climate-change-launches-first-ever-report. Accessed 15 Nov 2019
Woodward A, Macmillan A (2015) Environment and climate change. In: Oxford textbook of global health, 6th edn. Oxford University Press, Oxford, UK, pp 201–215
World Bank (2009) World development report. Development and climate change. Washington, DC
World Health Organisation (2002) Reducing risks, promoting healthy life. World Health Report, Geneva. http://www.who.int/whr/2002/en/
World Health Organisation (2017) WHO methods and data sources for global burden of disease estimates 2000–2015. World Health Organisation, Geneva
World Health Organisation (2018) Climate change and health. http://www.who.int/news-room/fact-sheets/detail/climate-change-and-health. Accessed 20 Mar 2020
World Health Organization (2008) The global burden of disease geneva
Young PR, Lisa FP, Hall RA et al (2014) Arboviral infections. In: Manson's tropical diseases, 23rd edn. Elseiver, Cham, pp 129–161
Zhou X, Yang G (2008) Potential impact of climate change on schistosomiasis transmission in China. Am J Trop Med Hygiene 78(2):188–194