

## REVIEW PAPER

## Impact of Climatic Change on Human Health

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### ABSTRACT

*The present paper is for the better understanding about the immense potential health effects of climate change. Climate change is the greatest health threat of the 21<sup>st</sup> century with implications for food production, water and health. The average global temperature has risen approximately 0.6° C over past century. World health organization has already documented the “human health effects of climate change” under a high priority research agenda. Climate change affects the health of individuals directly and indirectly. The effect of climate change varies by region, relative vulnerability of population, by the extent and duration of exposure and society’s ability to adapt to the change. In India one of the major consequences of climate change will be lack of food causing malnutrition and disease. Further, the modern food system which is a direct or indirect outcome of climate change is affecting health. Factors like exacerbation of unsafe water, disease, malnutrition, lack of awareness and nutritional knowledge affects the health. Extreme temperatures lead to air and water pollution which in turn may affect human health (respiratory, cardiovascular, various vector borne disease, emotional disturbances etc.). Any health related disaster (floods, draughts etc.) may cripple the already inadequate public health infrastructure. The risks of not only vector borne diseases like malaria, dengue fever, yellow fever, and encephalitis increase but the risk of diseases like diabetes, hypertension and other lifestyle disease also increase. The cause of diseases like migraines, indigestion, acid reflux, constipation, unexplained body pains, fatigue etc are untraceable. It can be due to climate change and changed food habits and availability. It’s reported that 35% of green house gas emission is by chemical agriculture, meat and food industry. Therefore, a vicious cycle is formed. With the food sector being contributing about one third of carbon emission today and affecting the health otherwise too, there is no option but to review the situation. Response options to protect health from effects of climate change include mitigation and adaptation. Further, High quality research is needed to strengthen the awareness programmes and policies designed to influence environmental factors that affect human health. There is an urgent need to underpin the awareness programmes and nutrition campaigns at grass root level. Definitely, whatever is good for earth is good for human body too.*

**Key words:** Climate; Health; Nutrition; Awareness;

Climate change is not just an environmental issue but also a health issue. No species can survive without a suitable environment. Climate change is expected to be ecologically and socially transforming. The scientific consensus support the fact that the global climate is changing in a way that has major implications for human life. Over the past few decades, it has become evident that human actions are changing atmospheric composition, thereby causing global climate change. Global mean temperature is expected to rise by minimum 1.80 C to maximum 7.10C over next 100 years with possible effects like more volatile weather patterns, increased incidence of hot spells, droughts, intense

rainfall etc. (John, 2005). Climate change is a long term phenomenon with potentially unpredictable, significant and long-lasting effects on humans (WHO, 2008a). A changing climate is likely to affect all the fundamental life support conditions and hence have a powerful impact on human health and well-being (McMichael, 2003). Therefore, climate change and health has become an important topic for public health and development institutions and researchers and is ultimate health issue (IPCC, 2007a).

*Climate change increase the risk of health through many pathways:* The food we eat, the air we breathe, the water we drink and exposure to extreme weather

events and infectious diseases found in nature. According to *WHO, 2008a* the effects of climate change will be more intense among poorer populations at low altitudes, where the most major climate-sensitive health outcomes, malnutrition, diarrhoea and malaria are already common and vulnerability to climate effect is greatest. There are health problems which are not created by climate change; rather they may be exacerbated or intensified by changing weather patterns e.g. diabetes, hypertension, malnutrition etc. (*Michael, 2006*). WHO estimates that a third of the global burden of diseases for children is due to modifiable factors in air, water, soil and food (*Mc, Micheal et al, 2008*). The natural disasters occurring due to change in climate lead to migration and increased poverty. Poverty is in turn both directly and indirectly associated with ill health, limited access to safe water, sanitation, nutrition and health care (*WHO, 2008b*).

Various researches are in progress relating to the links between climate change and health. Due to lack of data it is difficult to assess the current state and future trends in environmental changes and their effects on health. For example, without accurate statistics on health outcomes such as respiratory diseases in relation to outdoor air pollution, diarrhoeal diseases due to lack of access to water and inadequate sanitation associated with natural disasters, we cannot grasp how changes in the environment affect human health. Climate change affects the crop yields, which is associated with food production and risk of malnutrition. Malnutrition interacts with and aggravates diseases. (*Neira et al. 2008*). Therefore; studying impact of climate change on health is an important issue.

*What is climate change?:* Climate change can be defined as a change in the statistical properties of the climate system when considered over long periods of time, regardless of cause (*IPCC, 2001*). Human activities over the last 50 years – particularly the burning of fossil fuels – have released ample quantities of carbon dioxide and other greenhouse gases to affect the global climate. The greenhouse effect is caused by carbon dioxide and other greenhouse gases (GHGs) that allow heat from the sun into the atmosphere then trap it like a blanket. The atmospheric concentration of carbon dioxide has increased by more than 30 per cent since pre-industrial times, trapping more heat in the lower atmosphere. Human kind's activities are altering the

world's climate continuously by increasing the atmospheric concentration of energy-trapping gases (greenhouse gases [GHGs]), thereby amplifying the natural "greenhouse effect" that makes the Earth habitable. An increase in carbon dioxide and other greenhouse gases (GHGs), like methane, ozone, nitrous oxide, and chlorofluorocarbons, in the atmosphere is expected to increase the average global temperature. This in turn will lead to changes in rainfall and snowfall, more intense or frequent droughts, floods, and storms, as well as a rise in sea level. It is difficult to enumerate the effects of global warming because of the complex relationships between air temperature, precipitation quantity and pattern, vegetative cover and soil moisture. Though, it is likely that the incidence, intensity and duration of storms and other extreme weather events could increase.

Rapid industrialisation, deforestation and change in land use has not only increased the concentration of GHGs in the atmosphere, but also reduced the planet's ability to absorb GHGs. Therefore, an increase in the levels of GHGs lead to greater warming, which, ultimately lead to climate change.

*At risk population:* Entire world population is at risk of the impacts of climate change regardless of developing or developed countries. Only the severity will differ. Area wise people in developing countries, small islands, coastal regions and megacities etc. are more vulnerable. The most affected population will be of poor, children and elderly followed by and people with infirmities or pre-existing medical conditions. The developing countries with lack of medical facilities and health infrastructures will face more consequences to cope without assistance to prepare and respond. There can be intensely stressful situations such as increasing drought, decline in freshwater resources, and population displacement. Health effects can range from mental and emotional disturbances to the physical risks of conflict.

*Why India should be concerned?:* The resulting changes in the global climate bring a range of risks to health, from deaths in extreme high temperatures to changing patterns of infectious diseases all over the world. Population wise, India is the second largest country. As most vulnerable population to be affected from climate change will be children, elderly and poor. India with 27.5 per cent of the population still below the

poverty line is going to be affected majorly. Compared to other countries climate change is likely to have a greater impact on India because of the unique combination of its geography, varied population characteristics and extremely high carbon related energy dependence. Precisely at a time when India is confronted with development imperatives, we will also be severely affected by climate change. Several sections of the Indian population will not be able to buffer themselves from the effects of climate change specially the vulnerable groups like children and elderly. In India with the changes in key climate variables, like temperature, precipitation and humidity; vital sectors like agriculture and rural development are likely to be affected in a major way. Ultimately, Climate change is bound to affect the basic requirements, for maintaining health-clean air and water, sufficient food, adequate shelter and freedom from disease given the already high level of poverty, low nutritional levels and poor public health infrastructure in India (Vinay, 2008). Climate change will increase the burden of existing diseases by vector – borne diseases, intensified health stresses from extreme temperatures, impaired agricultural productivity, reduced crop yields and exacerbated existing health inequalities. (Joan, 2009)

The outcome of climate change in India will be excessively high, due to three main reasons: first geographical location, second high dependence of people on natural resources that are highly sensitivity to climate change, third low adaptive capacity due to fewer amounts of resources available to them. *Government of India's National Communications (NATCOM) (2004)* has identified various impacts of climate change like erratic monsoon in coming times will have serious effects on rain-fed agriculture, water and power supply, drop in wheat production by 4-5 million tonnes with each 1° rise in temperature, displacement of large number of people from coastlines, threatened fresh water resources, Increased frequency and intensity of floods (*European Parliament, 2008*). India should be concerned as water security is under threat everywhere with declining water tables, conflicts over rivers and basins, and the prospect of severely diminished freshwater resources due to glacier retreat in the Himalayas. This directly and indirectly impact the health of people. Most of the water borne diseases is due to unclean water or lack of water. Groundwater depletion

as a result of climate change has altered past trends in food availability, with expected implications for India's future nutritional landscape, rural-urban migration patterns, and disease burdens. Increase in average temperature lead to massive crop failures. All these factors affect the health of population directly or indirectly. Lack of appropriate medical facilities and awareness will make the situation grimmer (*Jeremy et.al. 2010*)

*What is impact of climate change on health ?*: The world's climate system is fundamental to life support. Populations of all animal species depend on supplies of food and water, freedom from excess infectious disease, and the physical safety and comfort conferred by climatic stability (*McMichael, 2008*). The general health of people relates mostly to behaviour, heredity, occupation, diet, activity, health care access etc but population health and survival depends upon the biosphere. The impacts, of climate change may be physical, ecological, social or economic but directly or indirectly it will affect the human health. Human health is directly affected with rise in global temperatures due to climate change which is expected to raise sea level, change precipitation, more frequent extreme events and other local climate conditions and indirectly through changes in water, air and food quality and changes in ecosystems, agriculture, industry and settlements and the economy. The climatic changes will have wide-ranging harmful effects including increase in heat-related mortality, dehydration, spread of infectious diseases, malnutrition, and damage to public health infrastructure. Climate change may affect health through a series of pathways—e.g., as a result of increased frequency and intensity of heat waves, reduction in cold-related deaths, increased floods and droughts, changes in the distribution of vector-borne diseases, and effects on the risk of disasters and malnutrition. According to *Campbell – Lendrum et al, 2005* the disease attributable to climate change relate to deaths caused by malnutrition, cardiovascular diseases, diarrhoea, malaria, accidental injuries in coastal floods and inland floods or landslides and the unavailability of recommended daily calorie intake (which is an indicator of malnutrition). All the factors make a vicious cycle and are interrelated. Drought and floods reduces overall consumption and variety in diets resulting in macro and micronutrient deficiencies. However, small increases in the risk for

climate-sensitive conditions, such as diarrhoea and malnutrition, could result in very large increases in the total disease burden. *WHO (2008)* declared that in the year 2004 diarrhoeal diseases caused 2.2 million deaths (3.7% global deaths) and malaria caused 0.9 per cent deaths (1.5% global deaths). According to studies by (*Mason et al, 2003*) malnutrition is responsible for approx.3.5 million deaths a year. More than one third of the disease burden in low income countries is due to malnutrition which is likely to be further aggravated by changing climate. Increased temperatures, rainfall, extreme disasters, air pollution, melting glaciers, rising sea level all affect the human health. Climate change is already leading to adverse health outcomes and it may affect further. At this early stage the effects are small but are projected to progressively increase in all countries and regions. The overall balance of effects on health is likely to be negative and populations in developing countries are likely to be mainly vulnerable to the adverse effect (*Haines et.al, 2006*).

Therefore, impacts of climate change on health can be summarised as:

- Climate change leads to changed disease pattern and mortality.
- Climate change impact will hit all the species and living being. The early signs like shift in the distribution and behaviour of insect and bird species depict that the biological systems are already responding to climate change.
- Impact will hit all the populations in all the countries by various factors only the intensity will vary. Most vulnerable population will be elderly, children and poor.
- Climate change will affect most fundamental prerequisites of health: food, water and air.
- Climate change influences the human settlements, migration, displacement and eating patterns, food habits resulting in malnutrition, injury, conflict and infections etc.
- More frequent extreme weather events will threaten the life of thousands of people by creating food and water scarcity leading to various diseases and infections. Public health security may be at risk.
- Rising sea level, extreme events may threaten coastal communities for survival and migration.

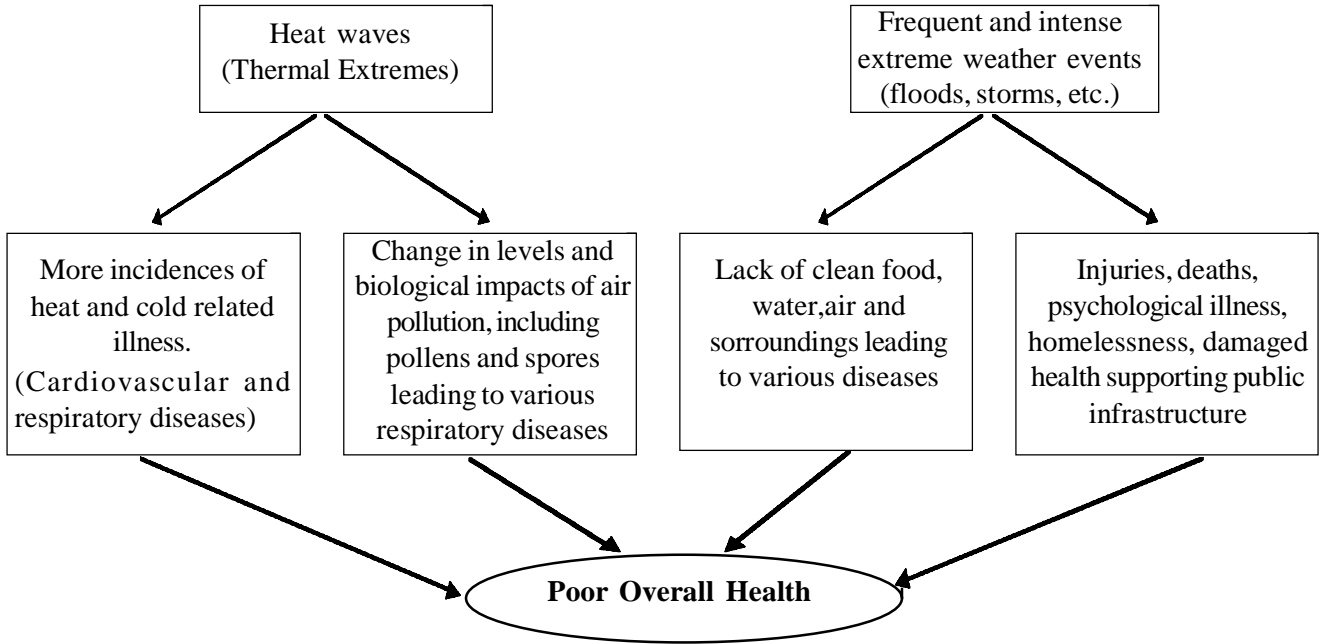
Mass environmental displacement and migration will disrupt the lives of hundreds of millions of people, exacerbating the growing issues associated with urbanisation and reverse successes in development.

- Fresh water scarcity risk may be more acute in coming times leading to related health problems and deaths.
- Changing weather patterns are already impacting food production and species migration and will further affect with more severity ultimately affecting human health and survival.
- Personal, social and emotional conflicts are increasing over strained ecosystems and will trigger further resulting in poor mental and social health.
- Climate change will have adverse effects on economic growth and ultimately affecting health. Economic collapse will devastate global health and development.
- Climate change influences the resurgence of disease organisms and vectors. Number of diseases may be exacerbated by climate change like: water borne disease, food borne disease, vector borne disease, diabetes, hypertension, obesity, food borne disease, respiratory disease etc.
- Climate change influences the stability of the ecosystems on which we depend. It influence the food production, distribution and consumption.
- As a result of climate change over food production, higher prices for fresh produce are likely to force those on low incomes to purchase lower quality, processed foods. This will further contribute to associated health risks such as obesity (*Wilmoth, P 2005*).
- Due to predicted changes in the amount and distribution of wildlife, fish and vegetation, crop production etc. there may be increases in diabetes, hypertension and obesity caused by the replacement of traditional food with processed food (*Wilmoth, P 2005*).

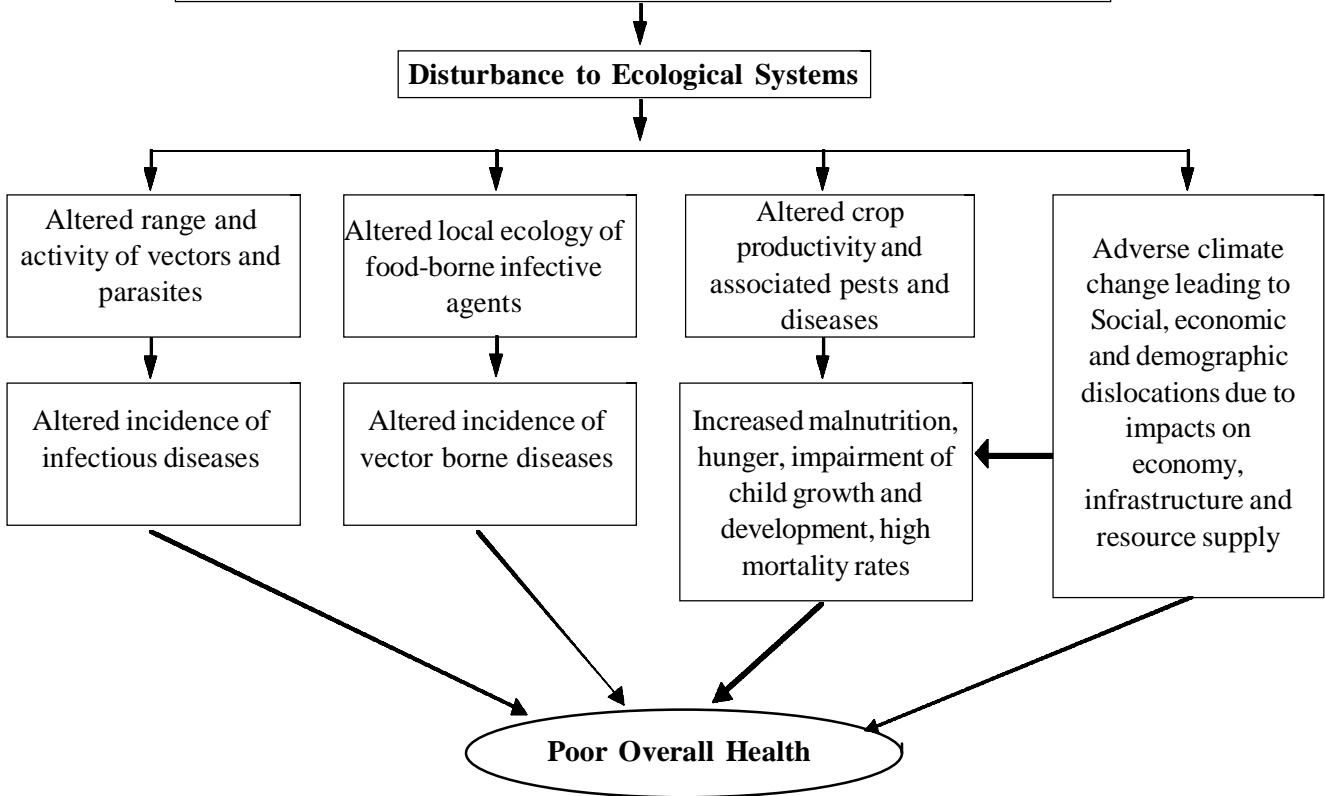
Therefore, climate change can affect human health both directly and indirectly.

*Direct effects of climate change:* Climate change can

**DIRECT EFFECTS OF CLIMATE CHANGE ON HEALTH**



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affect human health directly (e.g., impacts of thermal stress, death/injury in floods and storms).

- As climate becomes warmer, health problems increase. Frequent and severe heat waves and other extreme weather will increase the number of deaths. Due to concrete constructions, paved and tarred roads urban population will be more affected than rural. Raising temperature will increase in the areas of habitat of disease-spreading insects such as the mosquito, causing an increase in the transmission of infection through these carriers.
- The GHGs have been responsible for the reduction of stratospheric ozone, Depletion of stratospheric ozone results in higher exposure to direct harmful ultra violet rays of the sun. Exposure to harmful rays lead to an increase in the incidents of skin cancer especially in light skinned people, eye diseases such as cataract, suppressed immune system.
- Rise in temperature and air pollution caused by mass burning of fossil fuels releases carbon monoxide, sulphur dioxide, CFCs, and nitrogen oxides which can lead to cancer, respiratory disorder such as asthma and bronchitis, nervous system damage, headache, nausea, and loss of coordination.
- Water pollution and scarcity caused by various human activities, extreme weather events, chemical pollutants and waste discharge leaching to groundwater as a result there are more outbreaks of Gastroenteritis, jaundice, and cholera observed.
- Climate change is intensifying the circulation of water on, above and below the surface of the Earth — causing natural disasters like drought and floods to be more frequent, severe and widespread.

*Climate change and effect of extreme heat on health:*

The major impact of climate change is rising temperature. Changes in temperature patterns may disturb natural ecosystems, ecology of infectious diseases, increase in the distribution of malaria and other vector-borne diseases, harm agriculture, bring changes in food production levels and fresh water supplies, exacerbate air pollution levels, and cause large-scale

reorganization of plant and animal. Global temperature rise is directly affecting the health. Power plants, automobiles, deforestation etc. emit heat trapping gases which as a result warm up the planet. 2005 to 2010 are recorded as warmest years and overall a fastest rise in temperature is observed in 20th century. Extreme heat and higher temperatures increase the amount of moisture that evaporates from land water, resulting in droughts. Lands affected by droughts are more vulnerable to floods when rainfall occurs. The extreme temperatures affect the human health directly and indirectly both. As temperature raises so do the risks of heat-related illness and even death for the most vulnerable human populations.

Rising temperatures are likely to generate heat-related stress, increasing the short-term mortality rate due to heatstroke. Regions that are heavily urbanised will be more adversely affected than rural ones. In 2003, extreme heat waves caused more than 20,000 deaths in Europe and more than 1,500 deaths in India. Fluctuation in the climate especially in the temperature, precipitation, and humidity can influence biological organisms and the processes linked to the spread of infectious diseases. Vector reproduction, parasite development cycle, and bite frequency generally rise with temperature; therefore, malaria, tick-borne encephalitis, and dengue fever will become increasingly widespread. The extreme high air temperatures contribute directly to deaths from cardiovascular and respiratory disease, particularly among elderly people. *Robine et.al. (2008)* observed that high temperatures elevate the levels of ozone and other pollutants in the air that aggravate cardiovascular and respiratory disease. Warmer climatic conditions increase the range and life cycle of air, water, food or contact borne vectors causing illness. The UV radiation affects the immune system and cause infectious diseases especially of the skin. There will be more cases of skin cancers. Other trivial effects are increased incidence of skin disorders, such as prickly heat and fungal skin disorders such as ringworm and athlete's foot as a result of increased temperature. Susceptibility to skin infections such as Leprosy may increase by greater exposure to UV light. Extreme high air temperatures can kill directly. Higher temperature causes the sea levels to raise leading to erosion and damage to important ecosystems such as wetlands and coral reefs causing deaths and injury by

intense flooding. Temperature rise would indirectly result in geohydrological changes along the coastline such as saltwater intrusion into the groundwater and the wetlands and damage to the drainage in the low-lying areas.

Increased temperatures provide opportunity for various viruses, bacteria and parasites to contaminate food causing gastrointestinal diseases such as diarrhoea and vomiting, although occasionally more severe disease such as haemolytic uremic syndrome or hepatitis can result. Incidences of bacterial food borne disease increase during the summer months. The effects of diarrhoea, malaria and respiratory diseases are further confounded by under nutrition. Disease may restrict food intake, impair nutrient absorption, cause direct nutrient losses, increase metabolic requirements or catabolic losses and impair transport to target tissues.

*Climate change leading to natural disasters and its effect on health* : The Cause of severe storms, floods and droughts is warmer air resulting from greenhouse effect, which can hold more moisture and it evaporate surface water more quickly thereby increasing the frequency of severe storms, floods and droughts (Patz et al. 2000). Rising sea levels and increasingly extreme weather events will destroy homes, medical facilities and other essential services. The mobilization of people due to such risk factors results in the risk of a range of health effects, from mental disorders to communicable diseases. Data from various studies depict that the number of reported weather-related natural disasters has more than tripled since the 1960s, globally resulting in over 60,000 deaths every year, mainly in developing countries. In recent years, more than 2 billion people were affected by natural disasters, many of which were directly or indirectly related to extreme meteorological phenomena, including heat waves and cold waves, floods, droughts, and wind storms. Natural disasters such as floods and droughts affect human interactions with water resources and therefore exposure to the pathogen, and in addition, sanitary conditions and susceptibility to disease (Boxall et al. 2009).

Food and water supplies and nutrition are threatened in droughts and floods affecting the overall health. According to Watson et al (2007), the risk of infectious diseases in affected population is influenced by safe water and sanitation facilities, degree of crowding, and underlying health status of population, food availability and availability of health care services

within the context of local disease ecology. The long term effect of natural disasters is increase in communicable diseases caused by ingestion of contaminated water e.g. cholera and hepatitis A or contact with contaminated water. e.g. leptospirosis (Patz and Khaliq, 2002). Variation in rainfall result in floods causing water contamination, risk of water-borne diseases, and create breeding grounds for disease-carrying insects such as mosquitoes. A lack of safe water affects the hygiene and increase the risk of diarrhoeal disease (Arnell, 2004). A drought followed by an intense rainfall further lead to multiple disease outbreaks. These diseases can be rodent borne disease outbreak. Malnutrition, deficiency diseases, scabies, diarrhoeal diseases, conjunctivitis, trachoma etc. are the common diseases in droughts due to poor hygiene and lack of water and food. (Patz and Khaliq 2002, Prüss et al. 2008).

Sea level is rising every year and more than half of the world's population lives within 60 km of the sea which is likely to be displaced Nishikiori et al (2006) observed a significantly high mortality in children and women among the displaced population in the eastern coastal district of Sri Lanka after tsunami. Natural disasters such as flooding, drought and environmental degradation can lead to population displacement. Women and children account for a large proportion of displaced persons following natural disasters and are the most susceptible to adverse health effects such as malnutrition and outbreaks of diseases (Sapir, 1993; Chew and Ramdas, 2005). Extreme events like sea level rise coupled with stronger storm surges and coastal flooding can be followed by outbreak of diseases such as Cholera. (Vinay, 2008). Flooding also may lead to the contamination of waters with chemicals, heavy metals or other hazardous substances, either from storage or from chemicals already in the environment (for example, pesticides). Droughts have their largest impact on population health by threatening food supplies and nutrition. In addition, diarrhoeal diseases, scabies, conjunctivitis and trachoma are associated with poor hygiene and may result from inadequate sanitation as water resources become depleted (Patz and Khaliq, 2002; Prüss et al. 2008). Potential effects on health due to disasters include:

- Death and injury due to flooding, droughts, storms etc.

- Reduced availability of fresh water due to saltwater intrusion, lack of fresh and clean water.
- Contamination of water supply through pollutants from submerged waste dumps, floods, rise in sea level etc.
- Change in the distribution of disease-spreading insects
- Effect on the nutrition due to displacement, injury, a loss in agriculture land and changes in fish catch, shortage of food
- Health impacts associated with large population displacement.

*Climate change and its effect on water availability and health* : The impact of climate change on water availability is likely to be one of the most significant for the health of populations. Access to clean, safe water is still unavailable to more than 1 billion people Worldwide. Changing rainfall and temperature over the next decades are likely to make provision of clean water, good sanitation, and drainage even more complicated than it is now. The underlying risk factors due to climate change are further increased water scarcity, resulting in lack of safe drinking water, decline in water use for hygiene purpose.

Climate change effect severely to the water quality and quantity particularly in arid regions, small island states, and in regions hit by natural disasters where conditions of living are compounded by weakened infrastructure (Anderson et al., 2006). Lack of access and poor quality of water affect health through both chronic (e.g. arsenic) and acute (i.e. biological) exposures. Poor water and sanitation has been associated with increased risk of infections (Daniels et al., 1990; Huttly et al., 1990; Mertens et al., 1990) and increased malnutrition (Adair and Guilkey, 1997); Lack of fresh water compromises hygiene and hence increasing incidence and severity of diarrhoeal disease. Checkley et al., 2000 observed that diarrhoeal disease is a major cause of child deaths and it may increase by millions of cases worldwide. Factors like high temperature, low humidity and high river-level increase the incidence of rotavirus diarrhoea (Hashizume et al., 2007). About 40 per cent of the hospitalizations for childhood diarrhoea worldwide are attributable to rotavirus and more than 0.6 million children under age five die every year from rotavirus infection, mainly in

developing countries (Parashar, 2003). Ricci and Becker (1996) observed that improved water and sanitation was related to lower risk of malnutrition (Huttly et al. 1990; Daniels et al. 1990).

The effects of climate change on water availability and quality have implications for nutritional status (Prüss et al 2008, Fewtrell et al. 2007). The effects of diarrhoea, malaria and respiratory diseases on children are further confounded by under nutrition (Friedman et al. 2005, Mhrshahi et al. 2007). The effects of climate change on water availability and quality have implications for nutritional status (Prüss et al 2008, Fewtrell et al. 2007). Reduced river flows and increased water temperature will lead to declining water quality as the dilution of contaminants is reduced, less oxygen is dissolved in water, and microbiological activity increases. These effects could lead to major health problems for vulnerable people, especially during drought, and might increase the risk of conflict and major population migration.

*Climate change, rain and its affect on health*: The fact that rain is caused when heat from the Sun's rays on the surface of the seas, lakes and rivers induces evaporation. The water vapour formed in the process rises to a height where it condenses into moisture and rain. Due to climate change there is increase in the gases like sulphur dioxide and nitrogen in the atmosphere. When water vapours reach the atmosphere and condense they react with these gases atmospheric gases and form acid rain. When it rains, these atmospheric pollutants are deposited on the soil, vegetation, surface water or reservoirs. Acid rain releases aluminium and cadmium. Cadmium can cause kidney disorders, besides accumulating in the outer layer of the kidney, causing wounds. Aluminium on the other hand, causes problems for kidney patients. In dialysis- the process of purifying the blood when the kidneys malfunction- it enters the blood stream directly without first having passed the body's normal protective barriers causing skeletal and brain damage. Acidic rainwater also liberates mercury from the soil which can hinder brain development during the foetal stage. (Source: CSE Draft Dossier: Health and Environment, Climate Change and Diseases- The double Jeopardy).

*Climate change, air pollution and its effect on health*: Climate change could increase air pollution levels by accelerating the atmospheric chemical reactions that



produce photochemical oxidants due to a rise in the temperature. Due to human activities there may be increase of Chloro Fluoro Carbons in the atmosphere, resulting in increased UV radiation in the atmosphere.

Climate change is linked to air pollution both by its cause (greenhouse gas emissions) and by its effect (climate variability such as heat waves in urban areas leads to higher concentration of air pollutants). Economic and industrial growth has increased the level of air pollution. Increased allergic disease and asthma have been linked with ambient air pollutants such as nitrogen dioxide (NO<sub>2</sub>), ozone, particulate matter (PM), and components of PM including organic carbon and volatile organic compounds (VOCs) (McConnell *et al.*, 2002; McConnell *et al.*, 1999).

Increased levels of air pollutants and pollens aggravate asthma and respiratory allergic responses (Shea *et al.* 2008). Greater concentrations of carbon dioxide and higher temperatures may increase pollen quantity and induce longer pollen seasons (Beggs *et al.* 2005). Changes in the distribution, quantity and quality of pollens, in the timing and duration (lengthening) of pollen season is likely to increase the burden of diseases like allergies and asthma. Asthma and allergic disease are likely to be worsened because of interaction between heavier pollen loads and increased air pollution; thunderstorms and extreme precipitation events; worsening heat-related ground-level ozone pollution; increased ambient air pollution from natural and anthropogenic sources; and air pollution related to wildfires (Shea *et al.* 2008). Recent studies have suggested that air pollution is associated with infant mortality and the development of asthma and atopy. A 5-year follow-up study of young children in Australia showed that there was an association between air pollution and respiratory systems (Rodriguez *et al.* 2007).

*Climate change, food production and its effect on health:* Climate change threatens human health through its effect on under nutrition and food insecurity. Chronic and acute child malnutrition, low birth weights, and suboptimal breastfeeding are estimated to cause the deaths of 3.5 million mothers and young children every year. Furthermore, one in three children under the age of 5 years born in developing countries suffer from stunting due to chronic undernutrition. Climate change

will compound existing food insecurity. Before the current food crisis, more than 800 million people had calorie-deficient diets.

Rising temperatures, changing patterns of rainfall, and more frequent droughts and floods are projected to decrease crop yields in many developing countries causing shortages of food supplies. Scientists report a decrease in yield of crops as temperature increases in different parts of India. In India it is the poorest, most vulnerable farmers who practice rain fed agriculture. A temperature rise by 0.5°C in winter temperature is projected to reduce rain fed wheat yield by 0.45 tonnes per hectare in India (Lal *et al.*, 2000). This could result in severe malnutrition and under nutrition, especially among children, in countries where large populations depend rain-fed farming at subsistence level. Field, 2007 in his study showed that corn and soyabean yields fell by 17 per cent for every degree rise in growing season temperature. In another study they suggested that half of the world's population could face severe food shortages by the end of the century because rising temperatures take their toll on farmers' crops. Harvests of staple food crops, such as rice and maize, could fall between 20 per cent and 40 per cent as a result of increased temperatures during the growing season in tropical and subtropical regions.

Perhaps the greatest long term danger to human health from climate change will be the disruption of natural ecosystems, which provide an array of services that ultimately support human health. Biotic systems—whether in forests, rangelands, aquatic environments, or elsewhere—provide food, materials, and medicines; store and release fresh water; absorb and detoxify wastes; and satisfy human needs for recreation and wilderness. They are also intimately involved in sustaining the genetic basis of agriculture. Extreme temperatures and variable rainfalls also affect the rate of production of staple foods. (IPCC, 2007b). Data depicts that staple food production in African countries will be affected by up to 50 per cent by 2020. This will increase the prevalence of malnutrition and undernutrition, which currently cause 3.5 million deaths every year. Droughts, floods, infections, scarcity of food availability, affected food production all the factors increase the prevalence of malnutrition and under nutrition, which currently cause 3.5 million deaths every year.

Climate change, in combination with water and energy scarcity further adversely affects food security, creating a vicious cycle. Malnutrition is a major risk factor for disease (Lopez, 2006), and the effects of many diseases are mediated by nutrition. There is a bidirectional correlations between nutrition and diseases: not only does disease negatively impact on nutritional status, but undernutrition predisposes to different diseases including through lowering of resistance (Scrimshaw, 2003). Disease may restrict food intake, impair nutrient absorption, cause direct nutrient losses, increase metabolic requirements or catabolic losses and impair transport to target tissues (Stephensen, 1999).

*Climate change and its effect on diseases:* Climate is a major influence on all eco-system functions, and climate change and the sudden “threshold” shifts may lead to the emergence of new disease or health threats that are currently not foreseeable (Campbell-Lendrum, 2006). Due to rising temperature the infectious diseases are emerging, resurging and undergoing redistribution on a global scale. In addition to heat-related illness, climate change may increase the spread of infectious diseases, mainly because warmer temperatures allow disease-carrying insects; animal and microbes to survive in areas where they were once thwarted by cold weather. Vector-borne infections are affected by climate change (Checkley, 2000). In extreme heat pollen and other aeroallergen levels are also higher which trigger asthma. High temperatures raise the levels of ozone at ground level and other air pollutants, and hasten the onset of pollen season. Pollen and other allergens in the air trigger and aggravate asthma and cardiovascular respiratory diseases. (Vinay, 2008)

Warmer temperatures lead to shift in rainfall patterns and increase humidity which in due course affect the transmission of diseases by vectors like mosquitoes. They are quite sensitive to changes in temperature and rainfall and are among the first organisms to extend their range when environmental conditions become favourable. A one degree Celsius change in sea surface temperature, is seen to translate to an approximate 20 per cent increase in malaria cases (Mantilla et al. 2009). According to the WHO, malaria currently causes 350 million to 500 million illnesses annually (WHO, 2005a). Thus, higher temperatures could influence the incidence of diseases such as

malaria, dengue fever, yellow fever, and several types of encephalitis.

Increase in temperature also increases the population of microorganisms that cause waterborne diseases, such as *Vibrio cholerae* bacterium, which causes Cholera. Higher ambient temperatures foster the growth of pathogens that thrive in or on food, such as *Salmonella*. Other vector-borne diseases such as Schistosomiasis, Chagas disease, Sleeping sickness, River blindness, and various strains of encephalitis all could change their ranges and patterns of infection in the course of climate change. According to Hales et al. 2002 about 5–6 billion people (50–60 per cent of the projected global population) would be at risk of dengue transmission by later this century. Other vector-borne diseases that are affected by climate change and variability include (vector in parentheses) West Nile virus (mosquitoes), Lyme disease (ticks), Yellow fever (mosquitoes) and Leishmaniasis (sandflies). (*CSE Draft Dossier: Health and Environment, Climate Change and Diseases: The Double Jeopardy*).

Change in Climate conditions increase the intensity of water-borne diseases and diseases transmitted through insects, snails or other cold blooded animals. E.g. Malaria is strongly influenced by climate and it kills almost one million people every year – mainly African children under five years old. (Zhou et al., 2008). The vector of dengue, *Aedes* mosquito is also highly sensitive to changing climate conditions. Studies suggest that climate change could expose an additional two billion people to dengue transmission by the year 2080 (Hales et al. 2002).

Diabetes also shares common risks with climate change. Recent research tells us that countries with more obese populations generate more CO<sub>2</sub> emissions than those with less weighty populations. Well designed towns and cities with good public transport and food systems can increase physical activity and access to healthy food and simultaneously reduce diabetes risks and CO<sub>2</sub> emissions. (IDF, 2010)

*Possible health effects of climate change on mental health:* Human beings are subject to adverse psychological suffering from natural disasters and other outcomes of climate change. Mental health is difficult to measure as an outcome of climate change alone.

The likelihood of resource related mental health issues—ranging from depression to conflict—will increase dramatically (*Bradley Kreit, 2011*). According to the observations made by *Kar et.al.2007* a majority of the children had post traumatic symptoms (PTSD) which were clinically evaluated after a super cyclone in Orissa, India. Post traumatic stress disorder was observed among 30 per cent of the children. In another study by *Piyasil et al. 2007* nearly 60 per cent children were suffering from post traumatic stress disorder (PTSD) at six weeks after the tsunami in Thailand.

## CONCLUSION

Climate change is predicted to have substantial effect on human health. *Climate change has already transformed life on Earth*. Human activities has lead to climate change and eventually the after affects are the greatest sources of damage to the health of the people and planet (specifically, the life supporting biosphere) and they have a multiplying effect on other ongoing, pre-existent, global environmental and health

degradations. The number of diseases is seen to be aggravated by climate change, including vector-borne diseases, waterborne diseases and air-borne diseases, as primary causes of morbidity and mortality. Many of the major killers such as diarrhoeal diseases, malnutrition, malaria and dengue are highly climate-sensitive and are expected to worsen as the climate changes. Climate change affects the fundamental requirements for health – clean air, safe drinking water, sufficient food and secure shelter. Areas with weak health infrastructure – mostly in developing countries – will be the least able to cope without assistance to prepare and respond. Reducing emissions of greenhouse gases through better transport, food and energy-use choices can result in improved health. If we don't act now, climate change will rapidly alter not only the lands and waters but also the health scenario all over the world making it a different and difficult world.

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