Chapter 31

Global Warming and Climate Change : Health Implications

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The Intergovernmental Panel on Climate Change was established by the United Nations Environmental Program and World Meteorological Organization in 1988 to provide precise analysis of data related to climatic change. The panel issued a report in April 2007 on the impact of global climate change on human and animal populations (IPCC 2007a). The report is based on about 30,000 observations of changes in physical and biological systems worldwide. Greater than 90% of these changes are caused due to human activities such as fossil fuel combustion and deforestation (IPCC 2007b). The report in general warns of warmer temperatures, more precipitation with major part coming as rains than snow; more frequent droughts, bushfires, and extreme events like tornadoes and cyclones (McMichael *et al.* 2006).

Climate and its components such as temperature and precipitation are components of the ecosystem complex. Any change in these parameters also affects the biotic components such as vegetation, arthropod vectors, microbes, animal carriers and the human in an interacting and dependent way. This will in effect change the incidence and prevalence of disease in humans and animals in a complex manner. This is more tangible in the developing world where the factors such as nutrition, hygiene, population density etc. precipitate the outcome. There is now a realization of the “threat” and worldwide “concern” over the potential impact of global warming on the new spatial and temporal distribution of the global disease burden in the developing world. On the other hand the advanced countries hitherto had a semblance of immunity from the effect of climate on the prevalence of diseases, partly due to their high living standards, high per-capita expenditure on health, good nutritional status and lower population agglomerations. This is however changing now, and countries of Northern Americas and Europe are feeling the heat of new emerging and reemerging infections and infestations as a function of climatic change. Viral diseases such as West Nile fever in USA, Lyme disease or tick-borne encephalitis in Scandinavia, bluetongue in UK, and in Mediterranean countries of Europe are few glaring examples.

Fossil Fuels and Global Warming

Global warming, otherwise also known as green-house effect or glasshouse effect is the gradual increase in the earth's surface atmospheric temperature caused by man-made release of trapped carbon dioxide and some other gases in the atmosphere by large scale use of fossil fuels. This leads to trapping of excessive amounts of solar radiation in the atmosphere. Green-house gases are essential to maintaining the temperature of the Earth as these make planet warm and habitable, however, an excess of these may raise the temperature of the planet to lethal levels. According to a conservative World Health Organization estimate, 150000 people died in the year 2000 as a result of climate change, resulting from the 0.8°C global warming experienced over the past century. It has been estimated that, the average global temperature may climb by a projected 1.4-5.8°C over the century, and the annual mortality may double by 2020.

Fossil fuels are hydrocarbons, primarily coal and petroleum (liquid petroleum or natural gas), formed from the fossilized remains of dead vegetation by exposure to heat and pressure in the Earth's crust over hundreds of millions of years. Modern large-scale industrial development is based on fossil fuel use. With global modernization in the 20th and 21st centuries, the growth in energy production from fossil fuels, especially gasoline or petrol, diesel derived from oil and coal has increased immensely. Coal, one of the main fossil fuels, is being used by humans since long, although its increased use has started to come into being about two centuries ago.

From the onset of industrial age during the middle of 18th century, the energy needs of the human race have been increasing at a rapid pace. Before the advent of industrial age, the localized use of wind and water power at mills and universal use of animal power were the only means of production. In the later part of the 1700s the manual labour-based economy of the Great Britain began to be replaced by machines. The textile industries became mechanized and the energy needs were met by the increased use of refined coal. The development of canals, improved roads, railways and shipping for transportation was fueled by steam-power produced primarily by coal. The technology spread throughout Western Europe and North America during the 19th century, eventually affecting most of the world. In the critical century 1750-1850, the output of coal increased by about a factor of 10 (Pollard 1980). It can be disconcertingly seen that the usage of coal has increased by multitudes therby releasing a vast amounts of green-house gases into the earth's atmosphere. Coal remains an important energy source, due to its low cost and abundance when compared to other fuels, particularly for electricity generation. This means that its use is going to increase further! National Thermal Power Corporation consumed 130.71 million tons of coal in 2008-09 in its 79 coal-fired power generation units, which increased to approximately 150 million tons in 2009-10.

The other fossil fuel is oil or petroleum. Oil was known to civilization in the form of usage as asphalt and in medicine. The first commercial production of the oil started in around the middle of 19th century in USA. This production was mainly for supplies towards the demand of oil for kerosene and for lighting oil lamps. However, with the invention of Daimler and Benz modeled compression based internal combustion engines in late 19th century, the use of modern gasoline-based fuel driven transportation system took steam. This, in various steps of improvement, is still used in modern vehicles, although the magnitude and efficiency of its use has increased manifolds.

It can thus be observed that increase in population, rapid industrialization for economic growth fueled by demand from this populace and consequent high consumption of fossil fuels have led to release of increased amounts of green-house gases (Table 1.). The main green-house gases are carbon dioxide, methane, nitrous oxide, ozone, chloroflourocarbons and water-vapour, out of which water-vapour is the most abundant and powerful green-house gas and causes 36-70% of green-house effect. However, almost all of the water vapour in the atmosphere is of natural source, thus, little can be done about it. This brings us to carbon dioxide, which causes 9-26%, methane, which causes 4–9% and ozone, which causes 3–7% of the global warming effect.

Table 1. The tropospheric concentrations, residence times and atmospheric trend of various green-house gases (Source: IPCC 1997)

Parameter	**CO_2**	**CH_4**	**CFC-11[1]**	**CFC12[1]**	**N_2O**
Atmospheric concentration	[2]ppmv	ppmv	[3]pptv	pptv	[4]ppbv
Pre-industrial	280	0.8	0	0	288
Present (1990)	355	1.72	280	484	310
Current rate of change (%/year)	0.5	0.9	4	4	0.25
Atmospheric lifetime (Years)	50-200	10	65	130	150
Relative radiative effectiveness					
Per molecule	1	21	12400	15800	206
Per unit mass	1	58	3970	5750	206

[1]Chloroflourocarbon; [2] part per million volume; [3]parts per trillion volume; [4]parts per billion volume

Green-house gases are produced by many natural and industrial processes, which currently result in CO_2 levels of 380 ppmv in the atmosphere. Based on ice-core samples and records current levels of CO_2 are approximately 100 ppmv higher than during immediately pre-industrial times, when direct human influence was negligible.

The average global air temperature near the Earth's surface increased 0.74 ± 0.18°C (1.33 ± 0.32°F) during the hundred years ending in 2005 (Hegerl *et al*. 2007). The Intergovernmental Panel on Climate Change (IPCC) concludes "most of the observed increase in globally averaged temperatures since the mid-twentieth century is very likely due to the observed increase in anthropogenic (man-made) green-house gas concentrations" via the green-house effect. Rates of temperature change over the next fifty years range from 0.1 to 0.2°C/decade. Projections of sea level rise from 1990 to 2100 range from 25 to 49 cm, for mid-range climate sensitivity and ice-melt parameter values (IPCC 1997). A graph of global-mean surface temperature change from 1880 to year 2000 is shown (Fig.1).

Effects of Climate Change

A major part of global warming history has been filled with politics, debate and controversy on its authenticity, causes and consequences, notably in USA and Australia (McMichael 2001). However, the majority of climate scientists now agree that global warming is primarily caused by human activities such as fossil fuel burning and deforestation.

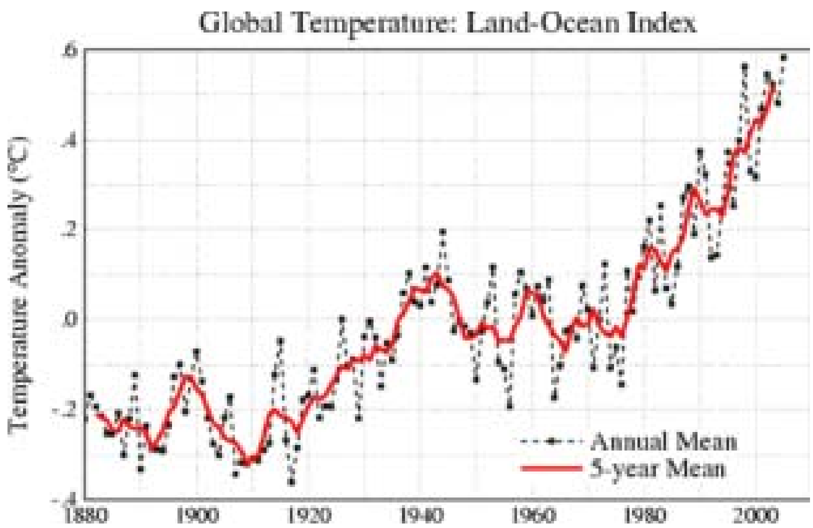

Fig. 1. Global mean surface temperature over the century (Image Courtesy NASA, Florida)

The primary effects of increasing global temperature include rise in sea levels, increase the intensity of extreme weather events like increase in floods and drought events, and change in the amount and pattern of precipitation. This in turn has other effects like changes in the agricultural yields, trade routes, glacier retreat, species extinctions and increases in the ranges of disease vectors. The increase in the frequency and severity of storms in many parts of the world is another significant effect. It has been observed that the number of Category 4 and 5 hurricanes has almost doubled in the last 30 years (Emanuel 2005). The flow of ice from glaciers in Greenland has more than doubled over the past decade (Krabill *et al.* 2004). Close to 300 species of plants and animals are geospatially affected by climate change evidenced by moving closer to the poles.

Increase in temperature has the potential to expand the range of infections that are normally constrained by temperature. This has led to the thinking that vector-borne diseases could spread to hitherto pristine areas of Europe and North America (Weissonbock *et al.* 2010). A graver scenario is envisaged in the areas of highlands within tropical countries such as East Africa and South America. In such areas where the temperature minima due to high altitude prevented the presence and breeding and therefore transmission of vector-borne diseases have now come under the zone of temperature where evidence of insect activity is now increasing. Many vector-borne diseases are now found at higher altitudes. Other diseases transmitted by mosquitoes like dengue and Japanese Encephalitis and arboviruses, such as Rift Valley fever, are likely to increase.

The most severe effect of global warming is most likely to be felt at the extreme climate regions of the world i.e. tropics, Arctic and Antarctic. The increase in the ocean level may lead to inundation of small island nations and resultant "poaching", salinisation and reduction in the land area in which people live, cultivate their crops, rear their animals and grow vegetables. The salinisation of fresh water ground aquifers with ocean waters will result in loss of potable drinking waters. Out of 20 major population agglomerations of the world, 13 are at sea-level. The water level rise and storms surges may result in major displacement of 50 to 100 million people from such areas resulting in major humanitarian and refugee problems with major public health disasters.

The major concern of increase in disease incidence due to global warming has been from Europe and US, however most severe effects of global warming may be seen in developing African and Asian regions with its high population density.

Global warming is also an issue with farm animals which are ruminants. This is because these animals emit methane into the atmosphere. Methane is second in terms of its effect to global warming after carbon dioxide. Methane is also produced from peat-bogs, wetland marshes and rice paddy fields as a result of anaerobic fermentation. Ruminants produce methane by digesting plant materials. It has been said that cattle and other ruminants are important sources of ozone-destroying global warming gases. Methane accounts for 4-9% of the world's green-house gases and only 7% of world's methane is produced by all ruminants (domestic and wild). Livestock though may be a major producer of methane into atmosphere by enteric fermentation, it is important for the humankind to keep it for converting fiber into food (Moss *et al.* 2000).

Epidemiological perspective

From the epidemiological standpoint the key elements of the host (animal and human), the disease causing agents (pathogens, parasites) and the micro- and macro-environment are always in a critical and tense opposing and power balancing flux. There is a highly complex, multilayered and intricate relationship between host, pathogens and the environmental factors which, over a temporal and spatial alignment, decide the outcome of a given event of disease. The global climate's continuous change and variation of temperature as an effect of global warming in a short span of time have added to the complexity of situation by bearing an unprecedented effect on all the three main elements of epidemiological triad. Many studies have been conducted with a focus on understanding the novel relationships between infectious diseases, climate and its impact on public health.

In a narrow sense of the word, climate is "the average weather". More precisely it is "the statistical description in terms of the mean and variability of relevant quantities over a period of time" ranging from months to thousands or millions of years. The classical period is 30 years as defined by World Meteorological Organization (IPCC 2002). Fig. 2 clearly shows that departure in temperature average has been significant in the last century and is projected to increase significantly (Henderson 2004). Climate can be divided into different components of temperature, rainfall and wind which have a marked influence on propagation of disease vectors and agents, their transmission and control.

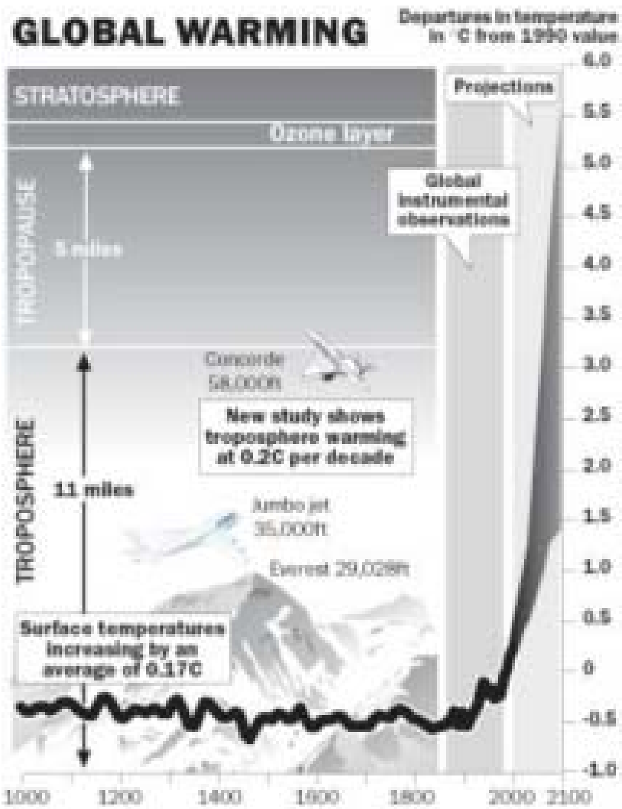

Fig. 2. Significantly rising temperatures over the century

Temperature varies by distance of a location from the equator, by the altitude of a place, local and other prevailing winds, size of land masses and ocean current influences. Temperature decreases with increase in the altitudes. Respiratory diseases are common in colder hills. Temperature also has a major effect on regulation in terms of frequency and magnitude of disease episodes. The malarial parasite has a shorter developmental cycle as the temperature rises, leading to a higher rate of transmission. The life cycle of a number of parasites are directly related to temperature. A large number of diseases, mainly communicable, are found mainly in the tropical areas.

Rainfall has a major contribution in the human industrial activity as it is an essential element in human agricultural production system. It helps people to grow crops, vegetable, rear animals and practice pisciculture. However, a scanty, untimely or heavy rainfall may lead to drought, failed crops, and difficulties in sustenance of animal rearing. Flooding may result in large scale agricultural devastation and consequent population migration. The receding flood waters often bring epidemics due to dead and decaying matter and increase in vector and vermin population.

Among the factors that exacerbate the health keeping abilities of humans and animals, the change in the landscape epidemiological parameters is critical. It provides a concomitant survival and perpetuation numerical advantage to vectors (generally insects) ecology. This is relevant to infections prevalent in tropical and sub-tropical climate, however global warming will instill a geo-climactic spread of vectors towards near-temperate latitudinal areas. Further, an increase in water, soil, air-borne diseases may result, as these are related to increase in extreme climate events like cyclones, flooding and drought. The dimension of socio-economic, nutritional and urbanization based factors will further complicate the outcome of disease events.

From the host standpoint, changes in the environment may trigger human migration, causing disease patterns to shift. Crop failures and famine may reduce host resistance to infections. Disease transmission may be enhanced through the scarcity and contamination of potable water sources. Importantly, significant economic and political stresses may damage the existing public health infrastructure, leaving mankind poorly prepared for unexpected epidemics.

The edifice of global warming is the key ingredient in the explosive mixture of factors which threaten to increase the burden of diseases of inhabitants of earth in near future. As the average temperature of atmosphere increases, even if by few degrees, it is going to have a tremendous effect on the global climactic energy distribution. For example, the melting of Arctic and Antarctica Polar Ice caps is going to increase the net solar absorption as ice reflects 90% solar radiation. This reflection will decrease to receding ice caps and resultant net positive radiation absorption. Consequently, the same ice-caps and icebergs which have melted into water are going to increase the volume, level and area of sea water. Two-third of the total population of the world lives within 400 km of a seacoast, and about half of it occupies a coastal strip 200 km wide. Out of Asia's total population of 4 billion, 60% live within 400 km of a coast. About 1.5 billion people live within 100 km of the sea (Hinrichsen 2008). Increase in sea level is going to inundate coastal areas normally and further inland in extreme climate events such as cyclones, due to which major humanitarian displacement problems may arise. Water has the tendency to absorb 90% of solar radiation it receives and increase the formation of water-vapour and cloud formation. This cloud formation is going to increase the frequency and amount of rainfall leading to high precipitation events and resultant flooding. Water-vapour *per se* also has a global warming effect although it is wholly a natural component. In addition to the receding snow fields, increase and expansion of shrub and sea cover and reduced ice-cover result in absorption of additional solar radiation thus warming the surface and atmosphere above (Foley 2005, Chapin *et al*. 2005).

Climate change and vector resurgence

During the past quarter of a century, there has been observation of the emergence, re-emergence and resurgence of epidemic vector-borne diseases affecting both humans and domestic animals (Gubler 2002). Bernard Vallat, Director General of the OIE said, "As a result of globalisation and climate change we are currently facing an unprecedented worldwide impact of emerging and re-emerging animal diseases and zoonoses" (Vallat 2007). Among the few main reasons responsible for this, anthropogenic environmental modifications seems to be cardinal (Rogers and Randolph 2000, Reiter 2001, Pherez 2007). Environmental and meteorological factors are known to affect the transport, survival, and growth of many disease-causing agents (Commission on Geosciences, Environment and Resources 2001, World Health Organization 2004). Insect vectors of many diseases and the pathogens they carry are temperature sensitive.

Table 2 summarizes the vector-borne zoonotic and animal infections prevalent worldwide. Global warming will certainly affect the abundance and distribution of disease vectors. Mosquito-borne diseases namely malaria, dengue and Ross river virus have been found to show seasonality patterns (WHO 2004). Such seasonal patterns of disease occurrence take place due to influence of components of climate on pathogen replication, vector population and spread, and on the hosts themselves. Altitudes that are currently too cool to sustain vectors will become more conducive to them. The understanding of seasonal patterns of diseases is one major pathway for overall understanding of long term climate change. Long term climate change has an effect on seasonal patterns through increasing the temporal window of active transmission season and chartering newer environments and going across old topographical limits (Harvell *et al.* 2002). It has been reported that in Sweden the incidence of Tick-borne encephalitis may result from early spring and mild winters (Lindgren *et al.* 2000). However, opinion of some other researchers with regard to Tick-borne diseases has been contrarian that climate change has not been the most significant factor in the epidemiology of tick-borne diseases (Randolph 2010). Some vector populations may expand into new geographic areas, whereas others may disappear. Malaria, dengue, plague, and viruses causing encephalitic syndromes are among the many vector-borne diseases likely to be affected. Some models suggest that vector-borne diseases will become more common as the earth warms, although caution is needed in interpreting these predictions. Clearly, global warming will cause changes in the epidemiology of infectious diseases.

Table 2. Vector-borne zoonotic and animal infections

Disease	**Vector epidemiology**	**Agent**	**Distribution**
	Viral Diseases		
Bluetongue	*Culicoides* midge bite. In Wild and domesticated ruminants (sheep) and camelids.	Orbivirus	North, Central, and South America; Africa; and parts of Asia; Mediterranean Europe; Middle East; and the South Pacific
African Horse Sickness	*Culicoides imicola and C. bolitinos* midge in horses, mules and donkeys. Zebras are resistant.	Orbivirus	Endemic in sub–Saharan central and East Africa, Egypt, Middle east, Mediterranean Europe
St. Louis Encephalitis	Mosquito-bird-mosquito cycle, amplification by *Culex nigripalpus, C. pipiens, C. quinquefasciatus, C. tarsalis, C. pipiens* complex.	Flavivirus	United States, as well as parts of Canada, the Caribbean, and South America

Japanese B Encephalitis	Water birds (herons and egrets) are the main reservoir. Pigs are amplifier hosts. Humans and horses 'dead-end' hosts.	Flavivirus	Cosmopolitan, especially in South east Asia, Outbreaks in South and N East India
Eastern Equine Encephalitis	Bird-mosquito transmission cycle is *Culiseta melanura,* In Horses and humans, *Aedes*, *Coquillettidia*, and *Culex* spp.	Alphavirus	N. America
Crimean Congo Hemorhhagic Fever	Hard argasid or ixodid ticks (*Hyalomma*)	Nairovirus	Endemic in Africa, Eastern Europe and Asia, Outbreaks recorded in Kosovo, Albania, Iran, Pakistan, and South Africa
Tick-Borne Encephalitis	Ixodid ticks and small rodents, Infection also by consumption of raw milk from goats, sheep, or cows.	Flavivirus	Europe, former USSR and Asia
West Nile Virus	Bite of *Culex pipiens*, *Cx. quinquefasciatus* and *Cx.restuans*., also *Aedes* spp. and other species in birds, horses, humans	Flavivirus	Worldwide, outbreaks notable in Uganda, Israel, S. Africa, Romania, Morocco, Russia, USA, France
Rift Valley Fever	*Aedes* spp. in cattle, buffalo, sheep, goats, and camels.	Phlebovirus	Endemic in eastern and southern Africa, sub-Saharan Africa and in Madagascar. In 2001, in Saudi Arabia and Yemen
Western Equine Encephalitis	Mosquitoes (*Culex tarsalis)*, other mosquitoes (*Aedes* sp.) and occasionally, small wild mammals in cycles of birds, horses, rarely humans	Alphavirus	North, Central, and South America; Plains of USA
Nairobi Sheep Disease	*R. appendiculatus* in sheep and goats	Nairobi Sheep disease virus; closely related to the Ganjam virus of goats in India	East Africa (Kenya, Uganda, Tanzania, and Somalia)
African Swine Fever	Soft tick *Ornithodoros erraticus,* Africa: warthog, bush pig, and giant forest hog; Europe: feral pigs	New family of African Swine Fever virus	African countries and on the island of Sardinia

Akabane Disease	Infection of bovine, caprine, and ovine fetus caused by intrauterine infection	Arboviruses of the Simbu group of the family Bunyaviridae	Japan, northern Australia, Israel Middle East, Cyprus, Korea, Zimbabwe, and South Africa. Serological surveys indicate Africa, Asia, and Australia
Louping Ill	By the sheep tick *Ixodes ricinus*, mainly in sheep, humans accidental hosts	Flavivirus	Endemic in Scotland, Northern England, Wales and Ireland
Lumpy Skin Disease	By biting insects like *Stomoxys calcitrans*, *Culex mirificus* and *Aedes natronius*	Capripoxvirus	Continents of Africa; few outbreaks in Israel, Kuwait
Venezuelan Equine Encephalomyelitis	Mainly equines and humans by mosquitoes of the genera *Aedes*, *Anopheles*, *Culex*, *Deinocerites*, *Mansonia*, and *Psorophora*	Alphavirus	Venezuela, Colombia, Ecuador, Peru, Guatemala, El Salvador, Honduras, Nicaragua. Costa Rica and Mexico
Wesselsbron Disease	Infection of sheep, cattle, and goats involved with *Aedes* spp. mosquitoes	Flavivirus	In warm and moist areas of African continent
	Bacterial diseases		
Lyme Disease	*Ixodes* spp., *I. ricinus* in Europe, *I. dammini* in north-eastern USA, *I. pacificus* in California and probably *I. holocyclus* in Australia. *Amblyomm americanum* is a possible vector in USA, deer, rodents	*Borrelia burgdorferi*	USA, Europe, Australia
Plague	Fleas	*Yersinia pestis*	No plague in Australia. & Europe; Endemic in Asia and extreme southeastern Europe , Russia, Middle East, China, India, Africa, N. America, S. America
	Rickettsial diseases		
Scrub Typhus	Rodent mites. The reservoirs: rats, mice and other small mammals	*Orientia tsutsugamushi* *Rickkettsia tsutsugamushi*	In typhus islands; Indian subcontinent to Australia and in much of Asia including Japan, China, Korea and parts of Russia

Murine Typhus	Rodent mites. The reservoirs: rats, mice and other small mammals	*R. typhi*	Indian subcontinent, Oceania, Russia and East Asia
Typhus	Squirrel ticks and flying squirrels	*R. prowazekii*	Eastern USA
Murine Typhus	Rats, cats, opossums, skunks, raccoons by infected rodent fleas, cat fleas	*Rickettsia typhi (R mooseri) and related species*	Worldwide
Rocky Mountain Spotted Fever	Bite of infected ticks, especially *Dermacentor variabilis* , *D. andersoni*; also from crushing ticks; rabbits, field mice, dogs	*Rickettsia rickettsia*	Canada, USA, Some parts of Central America and SE America
Rickettsial Pox	Bite of infected rodent mites, *Liponyssoides* spp	*Rickettsia akari*	Eastern USA, Africa, Russia
Heartwater	In cattle, sheep, goats, and antelope which is transmitted by ticks of the genus *Amblyomma*; Vector tick *A. variegatum* (tropical bont tick) found on cattle egret water bird in Caribbean nations.	*Cowdria ruminantium*	Endemic in areas of *Amblyomma* activity. In countries of Africa south of the Sahara, Madagascar, Tunisia , Caribbean countries
Q Fever	Sheep, cattle, goats, cats, dogs, rodents, other mammals, birds, ticks	*Coxiella burnetti*	Worldwide
Boutonneuse Fever, Tick Bite Fever	*Dogs, rodents*	*Rickettsia conorii* , related *Rickettsia*	Africa, Asia, Europe
	Protozoan diseases		
African Animal Trypanosomiasis	Cattle, sheep, goats, pigs, horses, camels, dogs, cats, and monkeys are susceptible In Africa, the primary vector for *T. congolense* , *T. vivax* , and *T. b. brucei* is the tsetse fly. *Glossina morsitans*, (open woodland, savanna); *G. palpalis*, (shaded habitat near rivers and lakes); and *G. fusca*, (high, dense forest). Mechanical vectors: *Tabanus* , *Haematopota, Liperosia, Stomoxys*, and *Chrysops*	*Trypanosoma congolense*, *T. vivax*, or *T. brucei brucei*	Africa- Southern edge of the Sahara desert to Angola, Zimbabwe, and Mozambique, only *T. vivax* occurs in the Western Hemisphere in at least 10 countries in the Caribbean and South and Central America

Babesiosis	*Boophilus annulatus, B. decoratus, B. microplus, B. annubtus, Ixodes ricinus, Haemaphysalis punctata and H longicornis* in cattle; *Dermacentor, Hyalomma* , and *Rhipicephalus* spp, *R. bursa, Haemaphysalis* spp in sheep and goats and *Boophilus, Hyalomma* and *B. microti.*, transmitted *by Ixodes dammini* in man	*Babesia. bigemina,B. bovis, B divergens, B. major, and B. ovata* in Cattle; *B jakimovi* in cattle and wild ruminants*; B. cabballi and B equi in* horses*; B motasi and B ovis in* sheep and goats*; B. trautnmanii* and *B. perroncitoi* in swines; and *B. microti* and *B. divergens* in man.	Worldwide depending on distribution of ticks
American Trypanosomiasis (Chagas Disease)	Triatomic bugs; The opossums, armadillos, rodents, and wild carnivores, cycle with bugs of the Reduviidae family serving as vectors	*Trypanosoma cruzei*	Central and South America
Surra	In Camel and Horses by biting flies such as *Tabanidae* and *Stomoxys*	*Trypanosoma evansi*	Africa, Asia and Latin America
Leishmaniasis (Kala Azar)	Transmitted by Sandflies Old World forms by *Phlebotomus*, and New World forms by *Lutzomyia,* wild mammals, rodents (rats), dogs	Cutaneous (*Leishmania major, L. tropica, L. mexicana*) and lethal Visceral form (*L. donovani, L. chagasi*) and 20 species and subspp.	South-east Asia, East Africa and Brazil, Europe;.Greater than 90% of cutaneous leishmaniasis cases occur in Iran, Afghanistan, Syria, Saudi Arabia, Brazil and Peru. More than 90% of visceral leishmaniasis cases occur in Brazil, India Bangladesh and Sudan
Tropical Theileriosis	Tropical theleriosis by *Hyalomma* in cattle	*Theileria annulata*	Tropical theileriosis is distributed in N. Africa, down the Nile Valley to Sudan, southern Europe, the

			Middle East, and parts of Asia, including the India & China
Bovine and Ovine Anaplasmosis	In cattle numerous tick vectors like *Boophilus*, *Dermacentor*, *Rhipicephalus, Ixodes*, *Hyalomma*, and *Ornithodoros* can transmit.	*Anaplasma marginale, A. ovis*	Occurs in tropical and subtropical regions worldwide (~40° N to 32° S), including South and Central America, the USA, southern Europe, Africa, Asia, and Australia

Vectors make use of a complex ecosystem which affects their survival and procreation and chances of further transmission (Table 3). The pathogen's success therefore depends on success of the vectors carrying pathogens. An increased precipitation and temperature favours vector survival e.g., mosquitoes causing malaria, however low rainfall and elevated temperatures favour novel habitat formations for *Phlebotomus* spp. causing spread of leishmaniosis. Scientists working in Emerging Diseases in a changing European eNvironment (EDEN) research programme reported an increasing trend in canine Leishmaniosis in Madrid and have proposed that environmental changes could have had an impact on vector and reservoir densities and their geographical distributions (Galvez *et al.* 2010). and their geographical distributionsIt has been reported that the temporal window of transmissibility of infection may increase or decrease depending on vector reproducibility and population (WHO 1990). The rate of development of pathogen in vectors is also temperature-dependent. Thus, for some vector-pathogen complexes, higher temperatures mean more infectiousness and higher vertical transmission rates, as in *Aedes*-dengue, whereas for *Culex*-Western Equine Encephalitis, cooler climates seem to exert a favourable effect (Watts *et al.* 1987, Diallo *et al.* 2000).

In the region of Camargue, West Nile Virus infection outbreaks were reported in humans and horses in 1960s (Panthier 1968), after which WNV probably remained low endemic, however the disease struck French equine populations with vigour in 2000 causing equine and human outbreaks throughout the first half of the decade (Murgue *et al.* 2001, Zeller *et al.* 2004). These outbreaks are attributed to abundance of *Culex* spp. from which virus isolations and transmission experiments have succeeded, all indicating a successful niche formation in southern France. These episodes of emergence of West Nile Fever and other mosquito-borne infections appear to be due to global warming although the authors have other justified reasons (Poncon *et al.* 2007). However climate change is now considered by some others as being responsible for the vector-borne disease recrudescence (Haines *et al.* 1993, Patz *et al.* 1996).

Table 3. Environmental factors determining the survival of vectors

Abiotic	**Biotic**
Temperature	Vegetation
Precipitation	Hosts (mammals, reptiles, birds)
Relative humidity	Natural predators
Wind	Parasites
Solar radiation	Pathogens of vectors
Topography	
Soil moisture	
Fresh water ponds, rivers, lakes	
Urbanization	
Educational status of community	

The change in climate may also shift the endemic distribution of disease e.g, an increase in mean ambient temperature in central Africa by 2°C has been considered to result in the disappearance of tsetse fly from the middle Africa southwards (Roberts, 1988). In case of trypanosomoses of domestic animals this would mean increased infection rates. Other vector-borne parasitoses like leishmaniosis and filariasis may increase in incidence (WHO 1990, McCally and Cassel 1990).

As the global warming will have major impact on the total volume and distribution of precipitation, this will also impact world agriculture and thus food production. Changing rainfall patterns will have considerable impact on irrigation, thus on choice and distribution of cropping, livestock rearing practices and utilization of farm inputs like fertilizers and pesticides. Irrigation patterns and cropping preferences will have impact on such diseases as schistosomiasis and Japanese B-encephalitis. The extreme climatic events such as droughts may have a beneficial effect by containment of many vector-borne diseases however direct nutritional effect of drought related crop failure on humans, and effect on grazing grass and shrublands on livestock health status may provide opportunity to other pathogens to cause infectious outbreaks. Drought and desertification have also a beneficial effect on certain vector-borne diseases such as dracunculiasis and leishmaniosis.

Livestock nematodal infection such as *Hemonchus contortus* in sheep and goats is an economic important disease, management of which is challenging due to worldwide emergence of anthelmintic resistance. An increase in diurnal temperature generally has detrimental effect on larval survival time in field, however, the infectivity of larvae has been found to increase over a wider range on exposure to higher temperature. The higher climate temperature may lead to the emergence of more infectious parasite (Roberts 1988).

Many viral infections are also vector-transmitted (Table 2). Viral encephalitis, Congo-Crimean hemorrhagic fever, Japanese-B encephalitis, Rift Valley fever, African Horse Sickness and bluetongue are few named here. The vectors of arboviral disease breed in a wide range of climates (WHO 1990) and rise in temperature and relative humidity due to precipitation may redefine the geographical distribution of such viruses. The rapid spread of West Nile fever in United states territories in 1990s is a startling example of rapid spread of a vector-borne viral disease over a whole continent in recent times (Rainham 2005). An increase in temperature shortens the reproductive cycle and extrinsic-developmental stages of some pathogens, thus, increasing the transmission chances, e.g, St. Louis encephalitis, Ross river virus infection (Liehne 1989). It can so happen that under certain conditions certain arbovirus infections which are presently endemic such as Kyasanur Forest Disease, Australian and Ross River infections may spread to newer areas assisted by international travels or extreme climatic events of cyclones.

Bluetongue, a debilitating disease of mainly small ruminants, has been conspicuous by its general absence from Europe. However, since 1998, six strains of bluetongue virus have spread across 12 countries and 800 km further north in Europe than has previously been reported. It has been suggested by the scientists that this spread has been driven by recent changes in European climate that have allowed increased virus persistence during winter. The general increase in average temperatures may have resulted in the northward expansion of *Culicoides imicola*, the main bluetongue virus vector. Probably, beyond this vector's range, transmission by indigenous European *Culicoides* species may occur, thereby expanding the risk of transmission over larger geographical regions (Purse *et al.* 2005).

The global warming has been considered to increase the events of extreme wind conditions like tropical and temperate storms and cyclones as a result of effect of temperature on air current and density. The recent confirmation of bluetongue outbreak in 17 cattle herds and in 8 sheep flocks in UK has been epidemiologically attributed to windborne vector transmission. The findings support the working hypothesis that infection was initially introduced into the counties of Norfolk, Suffolk and Essex by windborne transmission of infected midges from continental Europe (Anon. 2007).

African horse sickness virus (AHSV) infects equines and sometimes dogs. AHSV is endemic in sub-Saharan Africa and sometimes causes sporadic cases beyond this area. In the wild, the virus is transmitted between its vertebrate hosts almost entirely via the bites of arthropod vector; hence its global distribution is dependent on availability of arthropod vectors, susceptible vertebrates and presence of competent arthropod vectors. The major vectors of AHSV are certain species of *Culicoides* biting midge, which are true biological vectors but mosquitoes and/or ticks may also be involved to a greater or lesser extent. African horse sickness virus generally did not survive beyond its traditional endemic zones in sub-Saharan Africa for more than a couple of years. However outbreaks of AHS in Spain, Portugal and Morocco, have persisted for at least 5 years (1987-1991). The researchers have attributed this extended persistence to the 'all-year-round' presence in the area of adult *Culicoides imicola* which is an Afro-Asiatic species. However the moderation in climate may have lead to its increased ability of overwintering (Mellor and Boorman 1995). Continued studies in Portugal have indicated that distribution of this vector (*Culicoides imicola* Kieffer) was most consistent with that of previous outbreaks of *Culicoides*-borne disease. Its distribution was also broadly consistent with that predicted by a climate-driven model for modeling of *Culicoides* distribution.

The prediction about the nature and direction of changes in infectious disease epidemiology as a result of change in global climate is a highly complex phenomenon. Measurement of health effects from climate change can only be very approximate. Nevertheless, WHO has concluded that these impacts are likely to increase in the future. This rapid climate change is a harbinger of risks to human and animal health, particularly among the less privileged nations. The general burden of infectious diseases in less developed and developing tropical and subtropical countries of Latin America, Africa and highly populated Asia is particularly going to increase with the climate change. The factors like high population density, high rate of urbanization, effect of global warming on frequency of extreme weather events like coastal flooding, and inland flooding, droughts, cyclones and the effect of such events on agricultural productivity, food prices, food availability and affordability, food safety, nutritional adequacy, and general immunity of the population make these particularly vulnerable (Tirado *et al.* 2010). Weather extremes, such as heavy rains, floods, and hurricanes, also have severe impacts on health.

As the distribution and the amount of precipitation is changing, this will compromise the supply of drinking freshwater increasing risks of water-borne disease. Rising sea levels increase the risk of coastal flooding, and may necessitate population displacement. More than half of the world's population now lives within 60 km of the sea. Some of the most vulnerable regions are the Nile delta in Egypt, the Ganges-Brahmaputra delta in Bangladesh, and small islands, such as the Maldives. The increase in transmission seasons of important vector-borne diseases and change in their geographic range may expose new naive populations to be afflicted by such infections.

There is, therefore, a strong case for reduction of human influence on the global climate. The ability of mankind to react or adapt is dependent upon the magnitude and speed of the change. The outcome will also depend on our ability to recognize epidemics early, to contain them effectively, to provide appropriate treatment, and to commit resources to prevention and research.

Mitigation of health implications

If we plan for the warm future as it is going to unfold with its uncertainties, we may mitigate many of its carrier health effects. The economies of Asian countries which are rapidly developing also house some of the highest people per unit area of the world. The rapid industrialization and its dependence on fossil fuels is increasing by day. Therefore well-designed urban transport systems are needed to reduce green-house gas emissions. Given our past emissions, the world will continue to face a variable climate for at least several decades. We have to continue and increase fiscal support of programmes to combat infectious disease, improve water and sanitation services and respond to natural disasters in order to reduce health vulnerability to future climate change. Research in the field of vector-borne diseases affecting animals and humans needs to be given special emphasis. There is a pressing need to raise awareness of the health implications of climate change and related weather patterns. The voices of knowledgeable people like Dr. A. P. J. Kalam on the importance of nuclear energy clean energy as a substitute for fossil fuels must be listened to. Time is running out for strengthening the key components of health systems, such as disease surveillance and response, and health action in emergencies that are most needed to protect public health from the impacts of climate change. The optimisation of productivity of forage and food-crops by improving water and soil management and to improve the ability of animals to cope with environmental stress by management and selection is important strategic measures need to be taken (Nardone *et al.* 2010).

Conclusion

The doubts about the implications of climate change on human and animal health is fast receding, and scientific argument implicating the climate change effects on vector-borne and waterborne infectious diseases is moving towards preventive approach as compared to earlier skepticism. Climate change is taking place due to imbalance between the radiations in the atmosphere. The solar radiation is being absorbed in higher amounts by more quantity of greenhouse gases, mainly carbon dioxide and methane, resulting due to human activity and deforestation. Global temperatures are expected to increase by another 1.8 to 5.8°C by the end of this century. This is already affecting the patterns and incidence of infectious diseases that are transmitted by insect vectors and through contaminated water. The climate change has already resulted in the introduction of certain infectious diseases into previously unaffected geographic areas.

In an attempt to halt climate change, international efforts to reduce emissions have already been put in place. The Kyoto Protocol which has now been ratified by 187 nations and which came into affect in 2005 and which expires in 2012 has been blighted by non-participation by USA. Recently a meeting was held in Copenhagen to establish a framework of climate change mitigation after 2012; however, a binding resolution eluded the world. The usual deadlock question was the responsibility of developed countries in assisting developing countries in controlling emissions.

Although it is true that developed countries like USA are major guzzlers of fossil fuels and a significant contributor of green-house gases, developing countries also put enormous pressure on the natural resources by sheer number of their populace. We as an ancient country have an obligation to revisit the realms of our ancient wisdom in order to reengineer the concept of “development” and not fall into the traditional consumption based economic growth theory of the west. This will indeed be the best gift we can give to our children and to earth, of whom also, we are children!

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