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REVIEW ARTICLE

GLOBAL WARMING AND EMERGING INFECTIOUS DISEASES OF ANIMALS AND HUMANS: CURRENT SCENARIO, CHALLENGES, SOLUTIONS AND FUTURE PERSPECTIVES – A REVIEW

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ABSTRACT

Since the origin of earth temperature has played a significant role in the beginning of life on this planet. Continuous increase in the temperature of the earth is referred to as global warming that may have long term effect. Increased use of fossil fuels; use of natural gas and coal; population explosion; industrial wastes and agricultural fertilizers along with anthropogenic activities contribute to global warming. Increased level of Carbon dioxide (CO_2) also has a negative impact on the marine ecosystem. The outcomes of global warming include rise in sea levels and expansion of tropical and sub-tropical deserts. Importantly, the risk of contracting diseases both in human and animals increases. Increase in global temperature primarily by human activities, especially the burning of fossil fuels, has lead to the emergence of threat of diseases in human and animals particularly those of vector borne diseases like Blue tongue, West Nile, Japanese encephalitis, Dengue, Hanta virus etc. Species extinctions due to change in habitats and transport of livestock facilitates movements of viruses and arthropods (especially ticks) from one place to another. Variation of temperature and humidity have lead to increased growth of bushy plants, thereby increasing rodent population thus causing an increased risk of contracting various rodent borne infections (viz. Leptospirosis; Plague etc.). El Niño Southern Oscillation (ENSO) signal on vector-borne diseases due to changes in temperature have direct effects (in form of flood, famine, drought and extreme weather conditions of heat and cold) and indirect effects (in terms of changes in transmission and outbreaks of infectious diseases, especially of the diseases transmitted by vectors and vehicles) on human health. To mitigate the effect of global climatic change on infectious disease incidences and geographic spread, combined efforts consisting of mitigation to reduce further emissions of greenhouse gas; adaptation of intervention measures to reduce the damage caused by warming and geo-engineering (recycling) to reverse global warming must be properly implemented. In addition, vector control, improved reporting of animal diseases affected by climate change, strengthening of surveillance and disease investigation capacities in human and animal population, association and coordination of Medical and Veterinary institutions with various non-governmental organizations (NGOs) as well as international professional bodies and animal welfare organizations are all crucial to prevent and control emerging infectious diseases linked to global warming. Researchers, scientists, professional, environmentalist, administration, government and persons must work together to overcome this threat. The present paper describes the problem of global warming in general, its causes and multi-dimensional impacts, effect on animal productivity, interaction between climate change, pathogen and vectors, and presents a special focus on important emerging pathogens / infectious diseases of animals and humans being flaring up due to fluctuating environmental conditions, appropriate prevention and control measures to be followed to combat global warming in the current scenario and future perspectives.

INTRODUCTION

The Earth's climate system consists of complex interactions between many components including atmosphere (the gaseous part surrounding the earth), hydrosphere (liquid water, i.e. ocean, lakes), geosphere (consist mostly of rock and regolith) (IPCC, 2000). Since the origin of earth, temperature has played a significant role in the beginning of life on this planet. It is a well known fact that owe to excessive temperature, initially no life forms existed and yet along with other vital and physical factors temperature is one of the important crucial factor responsible for no life on other planets at present. In the history of earth, temperature gradually falls from higher to optimum and many lower to higher life forms viz; prokaryotes, eukaryotes (unicellular as well as multicellular), different archaebacteria, many unclassified infectious agents such as viruses, prions, and viroids originated. They are playing specific and defined role for their survival and for the equilibrium of the Ecological system along with the various atmospheric factors (Deimling *et al*., 2006; Jian *et al*., 2007). Different living forms inhabit at their suitable habitats either as autotrophs or heterotrophs in various kind of relationship as commensal, mutualistic, symbiotic, xenobiotic, parasitic etc. Being the most intelligent creature and on the top of the pyramid of Eco-system man learned to explore the nature deeply and exploit it wisely for a better future. For long and comfortable life man opened many new doors, discovered many a

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novel tools and techniques for leading a healthy life, conquered over various deadly diseases, started vaccination to check the disease before its occurrence itself, attempted genetic manipulations by conserving and cloning the genes of immortality to defeat the death, these were all made to fight long-lasting challenges for ever-continuation of life, and at the end an unavoidable condition of rapidly growing demands of food and shelter for the large and huge human population. Hence, deforestation, industrialization, use of chemicals such as chloro-floro carbons, air-water pollutants, fertilizers, projects targeting life searching on moon are on the picture to meet the requirement of food and land for the rapidly growing human population and in this journey somewhere equilibrium between vital and physical/atmospheric factors has been disturbed (Michaels and Knappenberger, 1996). An imbalance has occurred which was initially unnoticed for last few years but now due to natural or anthropological causes, direct or indirect effects and results of disequilibrium cannot be kept aside and ignored (Halacy, 1978; Hansen *et al*., 1999; Confalonieri *et al*., 2007).

In global terms, the effect of climate change vary quite dramatically among various parts of the earth and over the last 100 years an increase in mean annual temperature of the globe by 6°C (1.1°F) has been experienced. It is expected that this trend of global warming will continue to increase at dramatic rate. Between 1990 and 2100 AD it is expected that there will be an increase in surface temperature of the globe on an average by 1.4 to 5.8°C (2.5 to 10.4°F) and in the last 10,000 years such rate of temperature increase is faster than any other rate which is quiet alarming. The records and projected effects both global as well as regional climate changes must be assessed for better understanding of the impact of change in climate over the urban areas (Intergovernmental Panel on Climate Change, 2001). In regards to life science, for the continuous and sustained life an optimum balance between different factors of temperature, pH, relative humidity, salt concentration, water content, inorganic and organic compounds to act as fuel, concentration of gases in the atmosphere, limited microbial entry, colonization and harmful effects of infectious pathogens, favorable inhabiting conditions should be monitored regularly (Vorou *et al*., 2007). All the life forms cannot survive at one constant temperature and based on the temperature preference microorganisms have been categorized as psychrophiles, mesophiles, thermoduric and thermophilic (Brohan *et al.*, 2006). Similarly, higher forms of organisms also grow better at certain defined conditions and any deviation from such normal conditions either produces unfavorable circumstances to them or forces them to adopt accordingly for further survival.

Constant changes take place while acquiring the adaptation may be in terms of either different mode of life-cycle, change in habitat or change in host range (Epstein, 1999; World Health Organization, 2013). All these strategies of better survival under changing atmospheric conditions acts as route cause of new world emerging and many re-emerging diseases (Menne *et al*., 2005; Michael *et al*., 2009). Ocean temperature increases more slowly than land temperatures because of the larger effective heat capacity and more loss of heat by the ocean due to evaporation. Land temperature has increased about twice as fast as ocean temperatures i, e. 0.25°C per decade against 0.13°C per decade. Even though greater concentration of greenhouse gases is emitted in the northern hemisphere they do not cause any major difference in warming. This is because major green house gases persist long enough to mix between hemispheres (Sutton *et al*., 2007). Certainly, global warming is unequivocal and is primarily caused by increasing concentrations of greenhouse gases produced by deforestation and burning of fossil fuels (Battisti and Naylor, 2009; United Nations Framework Convention on Climate Change, 2011; Dhama *et al*., 2013a). In current scenario, constantly increasing temperature is a major concern, as it has its long term effects. Technically, continuous increase in the temperature of earth is referred as global warming which can be due to natural causes as sun is getting hotter day by day due to increased frequency of nuclear fission reaction in the centre of Sun, hence more heat is irradiated or due to human activities such as more industrialization, nuclear reactions, green-house effects of increasing concentrations of greenhouse gases produced by deforestation and burning of fossil fuels etc., also called as anthropogenic cause (Kaufman *et al*., 2009; Knight *et al*., 2009). Increased human population, changes in the ecosystem and biodiversity also plays a crucial role. All these causes related to change in ambient temperature have lead to precipitation of many factors and emergence of a wide variety of food- and water-borne diseases, zoonotic diseases including vector-borne diseases and pandemic viral diseases (Leonardi *et al*., 2006; Semenza *et al.* 2011a, 2011b; Dhama *et al.*, 2012a,b; Dhama *et al*., 2013a). The present paper describes the problem of global warming in general, its causes and multi-dimensional impacts, effect on animal productivity, interaction between climate change, pathogen and vectors, and presents a special focus on important emerging pathogens / infectious diseases of animals and humans being flaring up due to fluctuating environmental conditions, appropriate prevention and control measures to be followed to combat global warming in the current scenario and future perspectives.

GLOBAL WARMING

Gradual increase in the earth's surface temperature is called as global warming (Houghton, 1997). Earth’s temperature has increased with an average of 0.3- 0.7°C since 1900 and by end of 21^{st} century predicted to increase by 1.1- 5.8°C (IPCC, 2000). It is an average increase in the atmospheric temperature near the surface of earth and troposphere layer, which can influence the climatic patterns at global scale. The concept of global warming originated in 1896 by Svante Arrhenius, a Swedish chemist, when he mentioned the role of green house effect and proposed a theory that emission of carbon dioxide by burning of fossil fuels would cause increase in global temperatures by trapping excess heat in the earth’s atmosphere (Last, 1993; Grove, 1988). Life present on earth is an outcome of balanced interaction between lithosphere, hydrosphere, cryosphere, biosphere and atmosphere. Atmosphere is the main outer covering of earth consisting of different invisible layers *viz.,* troposphere, stratosphere, mesosphere and thermosphere towards cosmic. It clearly indicates that troposphere is the near most layer to the earth surface, hence it rapidly absorbs the emissions irradiated from the earth (Polyakov *et al*., 2003). Green house effect is based on green house gases such as carbon dioxide (CO_2), nitrous oxide (N_2O), water vapor and methane (CH_4) which have ability to absorb the irradiation, solar radiation and so the heat (Karl and Trenberth, 2003).

Solar radiations which fall on the earth are reflected back by clouds, absorbed by ice covering of earth and part of heat is absorbed by the green plants and green house gases which prevent the earth from becoming snowbergs (Liu *et al*., 2007). Green house gases comprise 1% of the atmosphere while 99% of the earth atmosphere is constituted due to non-green house gases such as nitrogen (N_2) and Oxygen (O_2). Because of the green house effect, earth maintains temperature suitable for life unlike other cold planets but constantly increasing concentrations of greenhouse gases in the atmosphere are creating a new problem of global warming due to adverse effects on biotic and abiotic both component of biosphere (Colwell *et al.*, 1998; Le Treut *et al*., 2007). Permafrost thawing is another critical component which supplements the global warming. Inter governmental Panel on Climate Change (IPCC) is exploring the potential impact of global warming on the climate of earth (Houghton *et al*., 1996; Watson *et al*., 1996; Venema *et al*., 2012). According to them, an increase of 31 % in CO_2, 151 % in CH_4 and 17 % in N_2O in the atmospheric concentration have been recorded since last 18^{th} century. It reflects that increased emission of greenhouse gases has direct correlation with rising global temperatures (Intergovernmental Panel on Climate Change, 2000; Folland *et al*., 2001; Venema *et al*., 2012). As far as the marine ecosystem is concerned climate change along with ever growing human pressures has profound as well as diverse consequences due to rise in the critical level of atmospheric carbon dioxide (CO2). The consequences primarily are increase in ocean temperature along with acidity. A wide variety of additional changes are created by climbing temperature that include rise in sea level; increase in ocean stratification; decrease in the extent of sea ice along with alteration in the pattern of circulation of the ocean as well as precipitation and input of freshwater. Both altered and warm circulation of the ocean in addition reduces the subsurface concentration of oxygen (O_2). In marine ecosystems, rate of physical as well as chemical changes certainly will almost dramatically accelerate further over the coming several decades provided if there is no immediate dramatic efforts towards mitigation of the climate (Bakun *et al*., 2010; Keeling *et al*., 2010; Doney *et al*., 2009 and 2011).

Causes Behind the Global Warming

The causes of global warming can be categorized into two classes: natural drivers and man-made drivers (anthropogenic). Naturally, large volumes of green house gases will be produced during volcanoes eruptions. Anthropogenic global warming is caused by human activities such as increased Carbon dioxide (CO_2) level, e.g. exhaust from cars/automobile use, burning of fossil fuels, coal-fired power plants, vast agricultural usage, deforestation practices, farming etc. (Tett *et al*., 1999; Battisti and Naylor, 2009; United Nations Framework Convention on Climate Change, 2011; Dhama *et al*., 2013a). Technologic facilities such as air travel, organ transplantation and demographic changes as migration from villages to cities are also among the important responsible factors. It is assumed that global warming is irreversible in nature. Global temperatures would remain close to their highest level even if the emissions are drastically reduced (Mahmood *et al*., 2006).

- The increased use of fossil fuels over the last 150 years has enhanced the production and release of CO_2 in the atmosphere. Fossil fuel burning and deforestation adds to release of CO_2 (Mann *et al*., 2009).
- Because of increased cost, more demand and less supply of petroleum fuel in developing countries, use of natural gas and coal as a fuel has become popularized which further adds to increased CO_2 emissions. Unfortunately, more concentration of CO_2 leads to increased intensities of hurricanes (Knutson *et al*., 1998).
- Around 30% of CO_2 release in the atmosphere is due to anthropogenic causes and it took 500 years to be completely cleared of from the atmosphere (Lindzen, 1997).
- Emissions of a precursor to the formation of sulphate aerosols i.e. Sulfur dioxide (SO_2) in the atmosphere also proves to be a cause of global warming (Buzorius *et al*., 2000).
- Cattle and sheep ranching, more cultivation, decay from landfills and mining cause methane (CH_4) level to rise in the atmosphere (Elanor, 2011).
- The livestock and agriculture sector is also responsible for greenhouse gas emissions through various ways including of enteric fermentation in ruminants, unmanaged manure pits (anaerobic decomposition) and agricultural practices like rice paddies with anaerobic bacteria, fertilizers used to grow crops, decaying vegetation and deforestation (Steinfeld *et al*., 2006).
- Population explosion can act as an essential cause and critical factor as more people means more food (especially from cattle) and more manure that indirectly increases the methane concentration in the atmosphere (Huesemann and Huesemann, 2011).
- Human activities account for 145% increase in methane concentration, once produced it can be maintained in the atmosphere for around 7-10 years (Intergovernmental Panel on Climate Change, 2000).
- Industrial wastes and agricultural fertilizers play a key role in production of N_2O gas (Patz and Balbus, 2001).
- Anthropogenic activities causes increase of N_2O by 15%, which has an average residence time of 140-190 years in the atmosphere (Wolfe and Patz, 2002).
- Automobile vehicles, home heating appliances and more consumption of electricity are other contributory factors towards global warming (Myrskylä *et al*., 2009).

Multi-Dimensional Impacts of Global Warming

Global warming is responsible for both economical and social changes. The agricultural productivity is primarily determined by climate. Considering the human welfare aspect of agriculture several federal agencies have expressed their concerns regarding the influence of climatic change on productivity in the agricultural sector. It is expected that change in climate influence livestock production in addition to production of crops. However, uncertainty prevails over the biophysical effects and their nature as well as the human responses to them (Adams *et al*., 1998). The temperature projections partly reflect the climate sensitivity, and sensitivity to projected warming which is greater due to higher estimates of climate sensitivity. It is important to understand that green house effect and global warming are two separate phenomenons, of course correlated with each other. Greenhouse gases, CO_2, CH_4 and N_2O have great capacity to absorb most part of infrared radiation energy and do not allow it to be escaped into the space. An increase in the concentration of greenhouse gases enhances greenhouse effect, which results into global warming. Long-term effects of global warming may vary all around the globe from stronger hurricanes, tides, cyclones and Katrina to the emergence and spread of important infectious diseases (Shope, 1991; Henderson-Sellers *et al*., 1998; Campanella, 1999). As per the projections made by climatologists, while reaching 2100 temperature may get increased by 5.8°C from present temp (Epstein, 2000; Committee on the Science of Climate change, 2001; Indian Ministry of Environment and Forests, 2004). Regional climate changes affect health of both humans and animals (Patz *et al*., 2005; Myers and Patz, 2009). Salient effects of global warming are enlisted as below:

- Increased global temperature causes melting of polar ice and glaciers which lead to rise in sea levels. It is believed that the contraction of the arctic ice cap is accelerating global warming. This usually affects the native people; wild life and plants (WHO, 2013).
- Alteration in the variance about the means and ice-core records of high resolution occurs due to a shift in the range of temperature and thereby it indicates that variance from climatic norms at a greater rate causes instability (Trenberth, 1999).
- Disturbance in normal weather cycle may cause expansion of tropical and subtropical deserts, change in the frequency and intensity of extreme weather events (hottest or coldest) cause fever of unknown origin (Dye and Reiter, 2000).
- Changes in agricultural yields or pattern are affected. Reduction in salinity of soil favors the emergence of toxic bacteria. Higher ocean temperature increases *Vibrio parahaemolyticus* (shellfish) (Schets *et al*., 2010).
- Due to climate change there is degradation of rangeland produced soil erosion, degradation of the vegetation cover and loss of biodiversity. Global warming is expected to further contribute to this degradation process (Thornton *et al*., 2006).
- Droughts and floods both will cause degradation of the soils (grazing and cropping). Climate change will accentuate salinization of soil and water. Increased salinity reduces the production levels (Masters *et al*., 2007).
- Increase of temperature results in changes in rainfall patterns and other water balance components like potential evapo-transpiration contribute substantially to water scarcity. Finally, there will be water competition between different strands of human activities. Rosegrant and coworkers (2005) reported that the global demand for non-irrigation water will increase by two-thirds by 2025.
- Some soil pathogens are picked up from soil and carried by dry dusty winds (Coccidiodes) (Smolinski *et al*., 2003).

- Due to more humidity and temperature in forest, bushy plants increases which favors population of rodents to increase (Bonnefoy *et al*., 2008; World Health Organization, 2013).
- Rise in temperature due to global warming also exerts physiological stress on many species and this might be the reason of their early maturity, under growth and even for the extinction of such susceptible species; as most of the marine organisms are severely being affected, and indirectly global warming has affected marine and other ecological system (Pearse and Balcom, 2005; Wilson and Swanson, 2005)
- Species extinctions due to change in habitats and transport of livestock facilitates movements of viruses and arthropods (especially ticks) from one place to another (Sakai *et al*., 2001; Sumilo *et al*., 2007; Schvoerer *et al*., 2008).
- Heavy rainfall creates new breeding habitats for vectors hence lead to high insect (mosquitoes, mites, ticks, flies and other insects) populations and influences the disease transmission dynamics and incidences of many infectious and zoonotic diseases, especially vector-borne diseases like those transmitted by poikilothermic arthropods (Matsuoka and Kai, 1994; Rogers and Randolph, 2006; Lafferty, 2009; Sachan and Singh, 2010).
- Prevalence of vector-borne diseases increases such as RMSF, malaria, encephalitis, lyme disease, dengue, and yellow fever (Martens *et al*., 1995b; Jetten and Focks, 1997; Rogers and Randolph, 2000 and 2006). There may be expansion of certain populations of vector into new geographic areas where as many of them may disappear (Martens *et al*., 1995a; Haines, 1998; Vorou *et al*., 2007).
- Water-borne diseases such as cryptosporidiosis and water toxicity or poisoning due to algal blooms are stepping ahead as a result of flooding owe to anthropogenic and natural causes (Atherton *et al*., 1995; Casman *et al*., 2001; Rose *et al*., 2001, Frumhoff *et al*., 2007).
- Effects of El Nino Southern Oscillation (ENSO) signal on vector-borne diseases due to changes in temperature have direct effects in form of flood, famine, drought and extreme weather conditions of heat and cold; and indirect effects in terms of changes in transmission and outbreaks of infectious diseases, specially diseases transmitted by arthropod vectors, mosquitoes, ticks, rodents, or through water on human health (Tunnicliff and Brickler, 1984; Aavitsland *et al*., 1996; Bouma and Van der Kaay, 1996). Global warming thus will clearly cause changes in the epidemiology of infectious diseases directly and indirectly (Bi *et al*., 2005; Khasnis and Nettleman, 2005).
- Temperature sensitivity governs the geographical distribution of several vector borne parasitic diseases. However in cold climate such parasitic diseases are either unusual or rare. For instance: in case of the four human species of *Plasmodium* the incubation period and the ambient temperature are inversely related (Cook, 1992).

Global Warming and Productivity in Animals

Thermal heat index (THI) is an equation which denotes the threshold level of the temperature and humidity at which animals starts suffering due to heat stress. THI index of animals ranges generally between 70 to 78 i.e., cattle, beef cattle, swine and poultry with approximately 72, 72-75, 72-74 and 70-80, respectively. From these THI values it is quite evident that slide elevation of temperature is going to affect adversely (Frumhoff *et al*., 2007). Global warming in a simple term is related to rise of atmospheric temperature and thus affecting all the biological activities which are dependent upon the temperature. Dairy industry or dairy animals comprise of the direct affected group. The increase in temperature is always a worry for dairy owner as the optimal temperature required for the maximum milk production is supposed to be in the range of 40°F to 75°F. However, it also depends upon the humidity level and higher level of humidity as 65 percent can cause heat stress even at 75°F in comparison to 30 percent humidity level where temperatures of 80°F can be well tolerated (Klinedinst *et al*.,1993). In such a sensitive issue where climate has already begun changing it is quite evident with the available information regarding rise of temperature in last few decades with the average rise in temperature being 0.5 °F per decade (Caldwell, 2007). Moreover, winter temperatures have risen in faster rate of 1.3°F per decade from 1970 to 2000 (Frumhoff *et al*., 2007). For dairy animals, the factors which are related to these climate changes are in many forms viz., increase in number of high temperature day; longer period of high temperature season and adverse conditions like storm and natural calamities, and all these adversely affect animal productivity. There are many reports of losses in dairy sector due to heat stress likewise in USA, where estimated annual losses to livestock industry were reported to be more than $2.4 billion (St. Pierre *et al*., 2003). Even more has been reported from the dairy herds of New York, where during the hot summer of year 2005 it got reduced even up to 5-8% of total production due to losses of 5-15 pounds milk per cow per day (Frumhoff *et al.*, 2007). Hot environment impairs production, metabolic process and health status of livestock. Heat stress leads to lower feed intake decline in the secretion of calorigenic hormones (growth hormone, catecholamines and glucocorticoids) which impairs digestion and metabolism (Webster, 1991). Blood glucose and non-esterified fatty acids (NEFA) are usually reduced in heat-stressed subjects and justified by the lower feed intake occurring in a hot environment (Itoh *et al*., 1998; Ronchi *et al*., 1999). Metabolic diseases are more commonly seen during hot weather conditions in livestock, examples include reduction in the amount of saliva and salivary content of HCO_3, which leads to increase in the susceptibility to sub-clinical and acute rumen acidosis (Kadzere *et al*., 2002). Dairy cows showed a higher incidence of mastitis during periods of hot weather (Chirico *et al*., 1997). Heat stress also reduces the performance of laying hens by reducing egg production, egg weight, shell thickness body weight and feed consumption (Mashaly *et al*., 2004).

Marine environment is also being affected by the global warming and the rise in temperature directly affecting the marine ecology (MacKenzie, 1988). The slight rise in temperature has adversely affected the production, life cycle and reproductive cycles of fishes and Whales in cold water (Greene *et al*., 2003; Greene and Pershing, 2004). The water streams, lakes of northern hemisphere which support the fish, wildlife and their aquatic ecosystems are adversely affected by alteration in stream flow and water quality and are ultimately affecting the fish recovery from ocean, lakes and rivers (Kennedy *et al*., 2002). Global warming is also adding a threat to the survival of native species of cold water ecosystem (Hayhoe *et al*., 2007). The aquatic species viz., brook trout, lake trout, Atlantic salmon, and several types of whitefish, which generally require water temperatures below 70°F are being affected more severely (Kennedy *et al*., 2002). The change in environmental temperature is also affecting ecological balance including of avian species and wild birds. It includes the demographical changes in bird populations and their reproduction and growth (Valiela and Bowen, 2003). It is also changing the distribution of insect population which indirectly affects animal productivity due to increase in insect borne diseases, as loss of birds mean the increase in insect population.

Global Warming and Emerging Infectious Diseases in Animals and Human Beings

A key determinant of health is climate. The range of infectious diseases is governed by climate while the timing as well as the intensity of disease outbreak is governed by weather (Dobson and Carper, 1993). Environmental changes due to global warming have always been linked with the appearance of new diseases or the arrival of old diseases in new places. For the purpose of driving the global emergence; resurgence and redistribution of infectious diseases an ever-increasing role is played by a warming and at the same time unstable climate (World Health Organization, The World Health Report, 1996). In past 30 years more than 30 new emerging or re-emerging infectious diseases have been recorded (Bissell, 1983; Bhatia and Narain, 2010). Among them water-borne, food-borne, increasing water toxicities, food poisoning, algal blooms, multi-host infectious diseases and vector-borne illnesses (viz. malaria, Japanese encephalitis, Kyasunur forest disease, West Nile disease and dengue) are quiet noteworthy (Sutherst, 1998; Slingenbergh *et al*., 2000; Craun *et al*., 2002; Dhama *et al*., 2010a). Factors responsible for these emerging diseases may be man influenced like population growth and density, urbanization, crowding, globalization of travel and trading, global climate change, microbial adaptation and changes in ecosystems (deforestation, loss of biodiversity), developing resistance of vectors to pesticides, indiscriminate and misuse of antibiotics in humans and domestic animals leading to increased susceptibility to various kind of infections, ageing, breakdown of public health measures, improper surveillance systems etc. and ultimately it is to be decided whether to choose mitigation or adaptation or to develop a path with the combination of both (Morse, 1995; Daszak *et al*., 2001; Taylor *et al*., 2001; Bengis *et al*., 2004; Wolfe *et al*., 2007; Jones *et al*., 2008; Myers and Patz, 2009; Cascio *et al*., 2011; Harlan and Ruddell, 2011). Climate change due to global warming may trigger an ecological invasion evolving a sorting process that brings genetic adjustment with evolution of new disease agents or complexes. There may be a continuous shift from an unusual disease flare-up to a recurrence of outbreak along with progressive range of expansion or invasion into novel territories and ecosystems. This causes shift in vector as well as host range.

In addition to creating conducive conditions to clusters of insect as well as rodent and water borne diseases immense threat to public health and the society as a whole is caused due to extreme climatic conditions (Epstein, 2001). Appearance of many new emerging pathogens as threats can be an early alarm of entry of various pathogenic agents from the planet which couldn't enter till now due to protective sheath of earth's atmosphere but gradually changing percentage of various gases in the ozone layer and temperature may lead to the evolution of many unpredicted infectious agents (Martens, 1998). Ultraviolet radiation due to depletion of ozone layer may lead to alteration in the human immune system thereby causing stress and making an individual prone to malnutrition (Patz *et al*., 1996; Kovats *et al*., 2001; Sakai *et al*., 2001; Kuhn *et al*., 2005; Mas-Coma *et al*., 2008; Bhatia and Narain, 2010). Gradually increasing climatic variability owing to multiple factors is further compounded by malnutrition because of the climatic pressure on agriculture, and adverse affect on human immune system could bring future population at risk of acquiring many infections and diseases of pathogen origin (Patz and Reisen, 2001). Rising upward trends in global temperature and climate changes, as a result of multiple determinants such as biological as well as human and ecological, causes increase in sea surface temperature and sea level leading to higher incidences of water borne illnesses and algal toxin related infections (Mouchet and Carnevale, 1997; Bezirtzoglou *et al*., 2011). Adverse effects of a warmer climate affect hygienic standards of food storage and may result into ill-effects like of food poisoning (Bentham and Langford, 1995; Longstreth, 1999; Patz *et al*., 2002). On the basis of available information it is quite evident that conditions like heavy rain fall, flood and surface runoff always produced waterborne diseases due to Giardia and Cryptosporidium (Curriero *et al*., 2001; Rose *et al*., 2001) and these conditions are raised mainly because of contamination of water supply sources (Frumhoff *et al*., 2007).

Interaction Between Climate Change, Pathogens and Vectors

Due to the emergence of infections in epidemic form on behalf of climate changes the impact of infectious diseases is made worse on public health. Such emergencies lead to increase in the evolutionary capabilities of micro-organisms alongside their capability to interact with human and animal; and environment. This results in occupation of ecological niches that are new with rapidity. Increase in the temperature has caused enlargement of spectrum along with diffusion of pathogenic agents and zoonotic diseases. This has a serious impact on public health resulting in evolution of epidemiological scenarios continuously (Tarsitano *et al*., 2010; Tarsitano, 2011). The climatic changes induced by global warming exert a selection pressure that will modify the biodiversity of pathogens and the epidemiology of the infections (Lovejoy, 2008). Many bacteria have developed mechanisms to survive and grow in unfavorable stress conditions over long period of time eg. *E. coli* O157:H7 survive in acidic condition at pH 2 after its earlier exposure to pH 5. Gene transfer between related and unrelated bacterial species and environmental adaptation leads to new microbes eg. non toxigenic *V. cholerae* strains acquired the genes encoding cholera toxin from bacteriophage and also emergence of Methicillin-Resistant *Staphylococcus aureus* (MRSA) (Mirski *et al*., 2011). Increasing CO_2 concentrations lead to stimulation of microbial growth as observed with increased fungal spore production (Coakley *et al*., 1999).

Higher humidity favors microorganisms to be more invasive in the host and inducing development of disease (Mirski *et al*., 2011). High temperatures and moisture leads to increased growth of fungi and production of mycotoxins (Lacetera *et al*., 2003; Dhama *et al*., 2013b). Rising sea levels lead to coastal floodings and risks for water-borne zoonoses (Naicker, 2011) and due to El-nino cycle increase in rainfall leads to more crops and food, which increases the rodent populations and rodent-borne zoonoses like Hanta virus infection (Engelthaler *et al*., 1999). The loss of biodiversity due to deforestation has an impact on the transmission of zoonotic diseases and alteration in seasons; changes in migration patterns leads to disease transmission from migratory water birds as Avian influenza (Gilbert *et al*., 2008; Dhama *et al*., 2008a; Dhama *et al*., 2013c). Global warming results in increased vector population growth rate, length of transmission period, invertebrate metabolic rate, egg production amount, feeding frequency and reduced duration of development period (Gubler *et al*., 2001). Increased temperature and rainfall along with increased population of vectors can extend territories of vectors to further latitudes which lead to emergence of vector borne diseases (Rogers and Randolph, 2006).

- Pea-farmers in South America are suffering with viral haemorrhagic fever due to clearing forests for agriculture purpose (Khan *et al*., 1998).
- Rapid enhancement in the emergence of hanta virus pulmonary syndrome in humans in the south-western United States is contributed by the volatile weather and heat spells that can disrupt long-term relationships between rodent species. The effect proves to be synergistic boosting mice populations more than ten-fold (Epstein, 2004).
- Cool temperature limit the development of malarial parasite in African territories but warm temperature or increasing temperature might intensify and extend the transmission of various vector borne diseases (Loevinsohn, 1994). This change further makes many a naive population susceptible to newly emerging pathogens (Epstein *et al*., 1998; Russell, 1998).
- Eating infected animals lead to new variant of Creutzfeldt Jacob disease (from bovine spongiform encephalopathy, BSE). The vast majority of this form of the disease has already been reported in United Kingdom (Centers for Disease Control, 2000).
- Reservoir (e.g., bats) activities may change to a great extent resulting in wide spread emergence of zoonotic diseases caused by Hendra virus, Marburg and Ebola; variant rabies etc. (Dhama *et al*., 2010b; Naicker, 2011).
- Similarly Nipah viral encephalitis (at pig farms in Malaysia) and West Nile virus (goose "fois gras" farms in Ramala, Israel) infection has occurred due to rearing of infected animals along with healthy/susceptible animals (Kilpatrick *et al*., 2008; Chakraborty, 2012).
- Trade of wild game is responsible for the spread of HIV in primates, Ebola, SARS infection (Eberhart-Phillips, 2000; Xu *et al*., 2004).
- Shift in the climatic changes may shift the distribution of ticks into new regions for spreading the infection like Lyme disease to

more people and animals. Lyme disease is influenced by Habitat Fragmentation and Biodiversity Loss which provokes high tick density and high tick infection towards development of Lyme disease (Praharaj *et al*., 2008; Dhama *et al*., 2013d).

- Distribution of rift valley fever depends greatly on migration of herds from one place to another that may be due to deforestation leading to rise in temperature which forces vectors to search for new susceptible hosts. *Culex* and *Anopheles* mosquitoes can serve as secondary vectors for the propagation of the outbreak and thrive well due to heavy rainfall which is by and large affected by the environmental temperature (Martin *et al.*, 2008). This may in turn facilitate spread of the disease in human.
- ENSO event has contributed to the outbreaks of rift valley fever in east Africa. Even fascioliasis in the Andes is also influenced by ENSO and global warming (McPhaden *et al.*, 2006; Mas-Coma *et al*., 2009).
- Similarly, ENSO has been found to make increase in the incidences of cholera in the parts of South America and many Asian countries (Lobitz *et al*, 2000; Pascual *et al.*, 2000; Speelmon *et al.*, 2000).
- Certain literature reveals that higher temperature has adverse effects on the growth and persistence of few agents such as Campylobacter, *E. coli* O157:H7 and enteroviruses (Hurst *et al*., 1989; Wang and Doyle, 1998; Thomas *et al.*, 1999; Rice and Johnson, 2000; Obiri-Danso *et al*., 2001). Though evidences are present which supports that cholera bacterium survives in the marine water even at rising temperature (Colwell, 1996).
- Emerging influenza infections in humans is associated with Geese, Chickens and Pigs because of occupational requirements (Dhama *et al*., 2008a; Dhama *et al.*, 2012a).
- After deforestation, owing to climatic changes or human causes, animal displacement in search of food is responsible for Lassa fever to be developed. Deforestation forces animals to come in closer contact with humans, resulting into increased possibility for infectious agents to breach species barrier between animals and humans. Wildlife populations, such as buffalo and lions in Kruger National Park in South Africa are affected by tuberculosis (Dazak *et al*., 2000).
- Arthropod vectors are most sensitive to climate temperature variability as mosquitoes, ticks and sandflies are ectothermic and have life cycle that are dependent on ambient temperature; may lead to spread of animal disease like blue tongue. Along with this penetration/ modification of unpopulated regions by human and close proximity to animal reservoirs/ vectors (Yellow fever, Malaria) lead to many diseases (Reiter, 1998a,b; Straetemans, 2008; Szmaragd *et al*., 2010).
- Certain infectious diseases has changed their pattern under the influence of climate change such as leishmaniasis, filariasis, tick-borne encephalitis in Sweden; Cholera in Bangladesh due to El Nino events; Increased incidences of Malaria in east African lands, dengue fever due to change in geographic region for maintenance of *Ae. aegypti* mosquito vector, rift valley fever in Africa and Middle east transmitted due to mosquito (Reiter, 1996; Craig *et al*., 1999; Reiter *et al*., 2004). These disturbances are attributed due to the direct effect of global temperature rise on activity and reproduction of vectors like mosquitoes and ticks thereby facilitating their expansion (Githeko *et al*., 2000; Gubler *et al*., 2001; Reiter, 2001; Singh *et al.*, 2008).
- In last two decades, due to fluctuations in the climatic temp significant increase in the population of *Ixodes ricinus* ticks has been observed in various regions of Europe (Kovats *et al*., 1999). This vector is actively involved in the transmission of tick-borne encephalitis, also called as TBE (Lindgren *et al*., 2000; Lindgren and Gustafson, 2001; Zeman and Benes, 2004; Randolph, 2008; Lukan *et al*., 2010).
- Climatic change like severe winter storms, floods and droughts can disrupt the normal movements of wild birds and can bring both wild and domestic bird populations into greater contact at remaining water sources, thus increase the chances of H5N1 avian influenza spread (Rosenberg *et al*., 1999; Dhama *et al*., 2005; Dhama *et al*., 2008a; Dhama *et al*., 2013c). Increased incidences of Acanthamoeba infection has been observed following flooding (Meier *et al*., 1998).
- Climate change causes rise in global temperature that increases the temperature of water bodies thereby increasing the chances of cholera caused by *Vibrio cholerae* (Curriero *et al*., 2001).
- Incidences of acute diarrhoea and respiratory syndromes have been recorded with more frequency with increased rate of floods and hurricanes (Campanella, 1999; Checkley *et al*., 2000).
- Because of increased temperature more evaporation from the ocean led to heavy rain fall and indirectly promotes growth and population of many vectors and so vector-borne diseases, very common example is malaria (Novelli, 1988; Lindsay and Birley, 1996; Rogers *et al.*, 2001).
- Various conditions such as cryptosporidium infection, cholera, hepatitis E, malaria, campylobacteriosis and higher incidences of leptospira infection in the area of Philippines and Rio de Janeiro are resultant of unusual flooding (Bouma *et al.*, 1996; Chan *et al*., 1999; Martens *et al.*, 1999; Lipp *et al*., 2002). Constantly increasing temperature causes melting of ice caps route cause of hike in sea level responsible for floods in low lying areas.
- Due to climatic changes and the unusual variations in rainfall/dry season patterns, there are chances of increase in incidences of Ebola hemorrhagic fever and closely related Marburg fever virus infection to man, gorillas, and chimpanzees (Leroy *et al*., 2004).
- Due to shift in the temperature and precipitation levels, the parasite survival in the environment increase and leads to increase in parasitic diseases among livestock, wildlife and man (Dazak *et al*., 2000; Dhama *et al*., 2013e).
- Changes in rainfall and temperatures will affect the distribution of rodent populations worldwide, which would influence the rodent-born diseases viz., leptosprosis, plague etc. (Chanteau *et al*., 1998; Leighton and Kuiken, 2001; Verma *et al*., 2012).
- Alteration in temperatures or food web dynamics due to climate change will increase the growth of harmful algae and cyanobacteria in and around water bodies leading to mass death of fishes, marine animals and human too. This phenomenon is known as Red tides (Dobson, 2009).
- Climate change makes impact on the availability of water sources particularly in drought conditions. This increases the effective contact of wildlife and livestock, resulting in increased transmission of the disease between livestock and wildlife and livestock and humans, for example as in case of Tuberculosis (Michalak *et al.*, 1998; Killian *et al.*, 2007; Dhama *et al*., 2013e).
- Any change in rainfall and temperature pattern can affect occurrence of fungal diseases like Cryptoccosis and Histoplasmosis in human due to high humidity and the disturbance of colonised soil facilitating release of spores (Greer *et al*., 2008).

Infectious diseases in terms of ill effects of climatic variation in general and global warming specifically can be grouped either on the basis of major causative agents such as viral, bacterial, parasitic, protozoal and rickettsial transmitted by vectors or based on the specific condition of temperature, rain fall, flooding, draught etc. Few important ones are summarized in Table 1.

Summer season or comparatively higher temperature of water bodies supports the growth of BGA and various planktonic species as copepods which are hazardous to health. Distribution of host and vector in the close proximity elaborates the epidemiology of such infections in more detail. Increased temperature, more rain-fall and resulting floods are inter-linked (Malilay, 1997; Greenough *et al*., 2001). It is important to understand the mechanism that how temperature is able to play active and significant role in disturbing the long-lasting set equilibrium of the nature. As temperature increases it disturbs the seasonality of the vector in causing disease by reducing or enhancing the survivability of such disease transmitting agents. Life span varies because feeding pattern, population growth rate, incubation period all parameters get affected and it has direct impact

Table 1. Important emerging pathogens / infectious diseases due to fluctuating environmental conditions

S. No.	Name of condition	Major cause/vector	Area at risk	References
1.	Chikungunya	Chikungunya virus, insects	Temperate climatic regions	Rezza *et al*., 2007
2.	Crimean Congo haemorrhagic fever	Nairo virus, Tick	Asia, Europe, Africa	Bente *et al*., 2010
3.	Dengue	Flavivirus, mosquito	Asia, Africa, Caribbean territories	Gubler, 1997; Hayes *et al*., 2006
4.	Filariasis/ Elephantiasis	*Wucheria bancrofti*, mosquitos	Tropical countries	Graves *et al.*, 2013
5.	Japanese encephalitis	Flavivirus, mosquito	Japan, tropical countries	Weissenbock *et al*., 2002; Solomon, 2006; Pawaiya *et al*., 2010
6.	Leishmaniasis, Kala Azar	*Leishmania donovani* and other *Leishmania spp.,* Sandfly Phlebotomus	Africa, tropical countries	Cook, 1996; Cross and Hyams, 1996; Singh *et al*., 2008
7.	Leptospirosis	*Leptospira spp.,* Flood induced or water-borne infection	Rio de Janeiro, New Zealand, tropical countries	Easton, 1999; Barcellos and Sabroza, 2001; Verma *et al*., 2012
8.	Lyme disease	*B. burgdorferi,* Ticks	United States	Estrada-Pena, 2002 Jaenson and Lindgren, 2011; Dhama *et al*., 2013d
9.	Malaria	*Plasmodium* spp., Mosquitos	Tropical countries	Mouchet *et al*., 1998; Walker, 1998; Rogers and Randolph, 2000
10.	Murray river encephalitis	Flavivirus, mosquito	Australian regions	Weissenbock *et al*., 2002 ; Kramer *et al*., 2011
11.	Plague	*Yersinia pestis,* Rat flea	United States and others	Nakazawa *et al*., 2007; Stenseth *et al*., 2006
12.	Rift Valley Fever	Phlebovirus (Bunya viridae), mosquitos	Africa, Kenya, Somalia, Egypt	Martin *et al*., 2008; Bhardwaj *et al.*, 2013
13.	St. Louis encephalitis	Flavivirus, mosquito	America	Hess *et al*., 1963; Kramer *et al.*, 1997
14.	Tick-borne encephalitis	Flavivirus/ Tick	Asia, Africa, Europe	Zeman and Benes, 2004; Danielova *et al.*, 2008, Daniel *et al.*, 2009
15.	West Nile Fever	Flavivirus, mosquito	United States and others	Easterling *et al*., 2000
16.	Hanta virus pulmonary syndrome	Hanta virus, rodents	United States, Central and South America	Epstein, 2001
17.	Trypanosomiasis	*T. cruzei, T. brucei* , Tse tse fly or bugs	Cental America and Africa mainly	Simon *et al*., 2012
18.	Yellow fever	Flavivirus, mosquito	Africa and America	Monath, 1999; Robertson *et al*., 1996
19.	Rocky mountain spotted fever	*R. rickettsii*, Ticks	United states	Hunter, 2003
20.	Relapsing fever, Typhus fever	*B. recurrentis, B. duttoni*, lice and ticks, respectively	India, Africa, China, Ethiopia	Hunter, 2003
21.	Boutonneuse fever	*R. conorii*, Ticks	Most parts of Africa	Parola *et al*., 2008
22.	Food poisoning	Multiple bacteria and their toxins	All over the world	Bentham and Langford, 2001; Kovats *et al.*, 2004
23.	Campylobacter infection	*Campylobacter spp.*	Most parts of world	Kovats *et al.*, 2005; Dhama *et al*., 2013f
24.	Cholera	*Vibrio cholera*, water-borne illness	Poland, India, Hungary and Germany	Colwell, 1996; Speelmon *et al*., 2000; Lipp *et al*., 2002
25.	Cryptosporidiosis	*C. parvum*, water-borne	North America, Texas, Europe	Smith *et al*., 1989; Atherton *et al*., 1995
26.	Estuary associated syndrome	Dinoflagellate, *Pfiesteria piscicida*	North Carolina	Morris, 1999
27.	Amnesic Shell fish poisoning (ASP), Red tides and neurotoxicity (NSP)	Water toxicity due to excessive toxin release by diatoms and dinoflagellates	Europe, Africa and north and south America	Hunter, 1998
28.	Respiratory illness, hepatitis, brown tides and harmful algal blooms (HAB)	Cyanobacterial algal bloom toxicity	European countries, north Queensland, Brazil	Skulberg *et al*., 1984; Saker and Griffiths, 2001
29.	Schistosomiasis	Schistosoma species	China, Africa, Brazil, America	Martens *et al.*, 1997; Mas-Coma *et al*., 2009

on the vector's capacity of transmitting agents as well as on the susceptibility of various vectors towards the pathogenic entity they harbor. On one side, more rain fall helps in production of dense vegetation and largely spread breeding sites for vectors but on the other side heavy rain fall may lead to flood which can eliminate natural habitat of many transmitting agents and this unfavorable situation acts as a driving force for inter species jumping (Day and Curtis,1989; Gubler, 1998). Perhaps, gradually changing environmental condition are favorable for many new emerging and re-emerging pathogens to find out their receptors in vast array of living beings on this earth, hence variety of new hazardous health deteriorating agents are coming into discussion, forcing us to look and plan for better and more wise strategies to fight against them in the race of survival (McMichael *et al*., 1996; Kovats and Haines, 2005). Since the advent of global warming and climate change, the environment is rapidly degrading. It is apparent that higher temperature for extended period of the year and many aberrations of seasonal variations in the climatic components are being witnessed. There is a strong consensus among researchers on the global phenomena of climate change especially its greater adverse effects in tropical countries including India. Higher environmental temperature invites the heat stress, a situation where animal cannot dissipate excess of heat to maintain its normal body temperature. Heat stress is compounded by many environmental factors including high ambient temperature, high humidity, direct or indirect solar radiation and wind speed along with resulting physiological disturbances such as failure of body heat dissipation mechanisms. It severely affects normal physiology, health and productivity of dairy cattle. Selection and breeding of superior genotypes for higher productivity of dairy animals assumes the presence of optimum environmental conditions. But in the scenario of climate change, thermotolerance is also an important trait to be considered while designing a breeding strategy for improved genotypes of dairy cattle (Ireland *et al.*, 2004; Kuiken *et al*., 2005; Kumar *et al*., 2006; Carter *et al*., 2009).

Measures To Combat Global Warming

Mitigation of Green House Gas Emissions

Global warming has a major impact on infectious diseases not only in terms of increased cyanobacterial blooms due to higher temperature but also owe to favorable climatic conditions for the survival and spread of vectors. The genuine and potential impact of fluctuating climatic conditions on the overall health is still far from the real prediction and much study is required to clear of such uncertainty (McMichael *et al*., 1998). Moreover, there are still many constraints of public health for the adaptation of climate change (Huang, *et al*, 2011). Altogether without any dispute prominent scientists, research workers and major scientific bodies are in concurrence of thought that the global warming is because of human-induced carbon emissions and inappropriate, uncontrolled, non-judicious utilization of sources of carbon (d' Hombres, *et al.*, 2010). Thus the threat of Global warming is fabric of God's creation "Human being" and so will affect more to those human and nonhuman who are least able to adapt. Thus the concept of to be good "neighbors" should follow across the globe to address global warming as it is a moral imperative and a challenge to humanity and absence of tolerance is also a major concern (Semenza *et al*., 2012). It implies certain steps to reduce the impact all over the globe with consensus.

- Reduce fossil fuel consumption, especially of coal to lessen the release of green house gases.
- Replacement of incandescent light bulb with compact fluorescent bulb at home or office, as replacement of such a single bulb can save around 150 pounds of CO_2 per year in long run.
- Recycling the garbage instead of decomposing by burning to reduce the production of more heat and gases like methane and thus ultimately reducing emission effect.
- Use of fresh vegetables, fruit and food material in place of canned or frozen food, fruits and vegetables as canned items contain additives or preservatives hence require more energy for processing.
- Promotion of biodegradation and recycling like the use of reusable cloth bags.
- Minimum use and decomposition of containers made up of plastic or polystyrene to avoid the release of toxic gases while their burning in the incinerators.
- Methane emissions during rice cultivation can be reduced by various practices like draining of wet paddy field once or several times during the growing season (Khalil and Shearer, 2006) or by using drip irrigation instead of flood irrigation system.
- Energy saving and alternative source of energy methods like energy saving stoves, construction of well ventilated house, hydroelectric power, wind energy, solar, biogas.

Reducing Enteric Methane Production

There are several set of nutritional strategies which proved efficient in decreasing methane production from livestock. O'Mara *et al.* (2008) and Martin *et al.* (2010) reviewed some options to reduce enteric methane production, which are enumerated as below.

- Feeding of concentrates instead of roughages results in increased amount of propionate in the rumen, results in decreased CH_4 production because least hydrogen is available.
- Less emission of CH_4 while feeding legume forages than grass-based diets.
- Methanogenesis is reduced by feeding ensiled forages.
- Administration of plant extracts (eg. condensed tannins, saponins, essential oils) also helps to reduce the CH_4 emissions. Tannins are having direct effect on methanogenesis and indirectly on hydrogen production due to lower feed degradation. Biologically active molecules from essential oils have antimicrobial properties and some are toxic to methanogens in the rumen. Using saponins and glycosides results in decreased protein degradation. Protozoa suppression is also induced by administration of saponins.
- Cotton seed cake and mustard cake concentrate mixtures in the diet significantly reduce methane production in buffaloes. Similarly, Na_2SO_4 @ 1.0 and 2.0g/kg in diet in of buffaloes results in decreased methane production
- There is a shift of bacterial population from gram positive to gram negative organisms while mixing of ionospheres (eg. Monensin) in the diet which results in shift of fermentation from acetate to propionate (Moss *et al*., 2000).

Manure management

Methane emissions can be reduced from stored manures by cooling, Handling manures in solid form (e.g., composting) rather than liquid form, mechanically separating solids from slurry, or by capturing the CH_4 emitted can be used as a renewable energy source (Paustian *et al*., 2004; Amon *et al.*, 2006).

Carbon sequestration

Soussana *et al*. (2010) reviewed that several management practices were used to increase carbon sequestration. Practices which help in grassland carbon sequestration like avoiding soil tillage, heavy grazing, agroforestry and grass-legumes association rather than grass only need to be followed. Popular media nowadays tells more about the disputes over the facts associated with global warming than scientific literatures do and such issues are thereby treated as resolved that too also more in the United States than globally. Global warming however cannot be avoided for decades with the strongest mitigation procedures. Implementation of adaptation measures thus is considered as the most practical action that can be taken for the adaptation to newly emerging conditions, however, these adaptations may also have adverse effects (Cheng and Berry, 2013). As a matter of fact it has been accepted that the impact of infectious diseases have not been apparent but will appear in one or the other form if global warming continues to progress in future (Boykoff and Boykoff, 2004; Emily and Shuman, 2010; Kurane, 2010).

Adaptation

Adaptive responses are made through many a ways viz., technological (raising more drought-tolerant crops and breed), behavioral (alterations in dietary choice), managerial (improved farm management practices), and policy options (planning regulations and infrastructural development). There are several options to adapt with climate change, which includes development of new variety crops and feeds, genetically improved drought tolerant breeds in livestock, control and prevention of human and animal diseases, providing cold water during hot and humid climate, provision of shade for livestock to reduce heat stress, keeping animals outside during night in summer, elevated animal house/shed/shelter and also development of early-warning systems and protection measures for natural disasters (droughts, floods, tropical cyclones, etc). (Kurukulasuriya and Rosenthal, 2003; Singh *et al*., 2012)

Prevention and Control

To control wide adverse effects, preventive strategies should be optimized for which inter-disciplinary cooperation is necessary among the climatologists, ecologists, biologists and policy makers with the help of geographically based data system, integrated modeling system such as climate general circulation models (GCMs) along with widely enhanced and circulated disease surveillance (Patz *et al*., 1998). Risk assessment based on rainfall and melting of icebergs acts as key factor in predicting risk of emergence of various new multi-hosts diverse infections more realistically (Rose *et al*., 2001).

- For the control of vectors- mosquitoes, application of insecticides and animal population control should be given due care. Along with this immunization, habitat modification, host exclusion as well as both on and off-host measures must be taken into consideration (Kilpatrick and Randolph, 2012).
- Improved reporting for animal diseases affected by climate change need to be followed with the help of multidisciplinary experts including epidemiologists, biologists, ecologists, meteorologists, and local authorities. It is moreover necessary to undertake initiatives for networking among epidemiological and laboratory units under public health and animal health sectors. Baseline data must be established especially in the developing nations that will help enabling generating predictive models as well as helpful for tracking (WHO/FAO/OIE, 2004; Dhama *et al*., 2013g; WHO, 2013).
- Strengthening of surveillance and disease investigation capacities in human and animal population along with public health appraisal and socio-economic impacts should be taken care of timely. Along with these, appropriate developmental activities in harmony to check cross-border disease and response activities are of utmost importance (Slingenbergh *et al*., 2000).
- The Environmental Protection Agency must play its role in recommending the proper ways in which individuals and businesses can reduce their greenhouse gas emissions. Medical and veterinary institutions should be involved along with various non-governmental organizations (NGOs) as well as international professional bodies and animal welfare organizations especially for control of global warming associated zoonoses (Brown *et al*., 1976; Sachan and Singh, 2010; Dhama *et al*., 2013a).

In this situation of emergence of many a diseases in the event of global warming, advances in biotechnology, molecular biology, immunology, genetics and nanotechnology need to be exploited to their full potential for formulating appropriate disease prevention and control strategies as per demand of the hour and thinking about the future dimensions viz., generating and applying rapid and confirmatory diagnostics especially supporting and strengthening the disease surveillance, tracking and monitoring systems; getting safer and effective vaccines for combating these emerging pathogens; and using novel and alternative therapeutic regimens along with following suitable prevention and control measures for checking the global rise in temperature and steps for alleviating its multidimensional effects (Jebara, 2004; National Research Council, 2005; Schmitt and Henderson, 2005; Belak, 2007; Bollo, 2007; Kahn *et al*., 2007; Ratcliff *et al*., 2007; Dhama *et al.*, 2008b; Paul-Pierre, 2009; Deb and Chakraborty, 2012; Dhama *et al*., 2012b,c; Mahima *et al*., 2012, 2013; Deb *et al*., 2013; Dhama *et al*., 2013g,h,i,j,k,l,m; Tiwari *et al*., 2013a,b). Problems like emerging antibiotic resistance also need to be taken care of by following judicious use of drugs and alternative therapeutics (Dhama *et al*., 2013j, k,l; Tiwari *et al*., 2013c). One health approach need to be practiced holistically to combat the emerging infectious diseases due to global warming and climate changes for safeguarding health of humans as well their companion animals (Ahmed *et al*., 2010; FAO Media Centre, 2010; FAO-WHO-OIE, 2010; The World Bank, 2010; Dhama *et al*., 2013a).

Conclusion and Future Perspectives

To mitigate the effect of global climatic change on infectious disease incidences and their geographic spread combined efforts consisting of mitigation to reduce further emissions of greenhouse gas; adaptation of intervention measures to reduce the damage caused by warming and geo engineering (recycling) to reverse global warming must be properly implemented. Most of National governments are agreeing to the Kyoto Protocol which aimed to reduce the greenhouse gas emissions and so to global warming. It is a fact that infectious diseases will continue to emerge, re-emerge and spread due to human-induced environmental changes which favors microbes and their vectors to produce opportunities to survive in the nature. In short, it may be concluded that to avoid such harmful effect of global warming, we should make small changes in our life style now only. Researchers, scientists, administration, government and persons must work together to overcome this threat. It is believed that members of the health care committee need to be responsible although it is the responsibility of the government to tackle climate change. Present scenario is indicating that within next few decades environmental conditions may become more conductive for the entry of unwanted harmful agents in the biosphere; hence there is an urgent need to envisage a full-proof strategy involving techniques of satellite imagery and remote sensing as a preventive measure against various unpredicted outcomes waiting to be expressed because of fluctuating climatic conditions. At last but not least the formation of an ecologically justified society led by the values of cooperation, sustainability, equality, fairness, and participation appears to be the only solution of the global warming where cooperation stands for combined efforts of all societies; sustainability refers to the judicious use of earth's limited capacity to provide resources in controlled manner and to absorb the pollution resulting from the utilization of resources; equality implies considering the values of good neighborhood irrespective of social and economical status; fairness tells about fair play by different organizations and government system for the equal distribution of resources and participation represents the involvement of all whole humanity without any hesitation. All these are possible with the development of such biological and social systems that nurture and support life by judicious use of existing wealth not by the concept of maximum utilization.

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