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Global Climate Change and its Impact on Environment and Public Health: Risks and Responses

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Abstract - *Global climate change is one of the biggest threats to the human population. Over the last century, the Earth's average surface temperature has been increasing due to global warming. Climate change impacts human health directly or indirectly by rising sea levels, higher temperatures, heat stress, degraded air quality, population migration, and extreme weather conditions like floods, earthquakes, droughts, volcano eruptions, tsunamis, etc. Some people are more vulnerable to this change than others because of their high level of exposure, improper management of the public health system by the government, poverty, etc. Factors like age, gender, geographic location, malnutrition, etc., may also impact public health on a large scale. If we don't take any steps to control the already deteriorating global climate, then it may ease the spread of infectious disease, vector-borne, water-borne, etc., Also, indirect effects like population migration resulting in stress, economic instability, loss of homes, etc., are of significant concern. This paper examines the impacts of global climate change on the environment resulting in mortality due to extreme weather events, ways to tackle these ongoing changes, climate change perspectives from different countries, vulnerability on the population of low-income countries, economic instability due to climate change, and its impact on some countries and the need for using sustainable and energy-efficient devices to protect our environment.*

Key Words: Climate change, global warming, health, environment, vector-borne disease, heat stress, droughts, water-borne, economic instability

1.INTRODUCTION

Many comprehensive aspects of climate change include increased average atmospheric temperature, ocean temperature, melting glaciers, and sea ice, rising sea levels, etc. Exposure of population to particulate matter(PM) and various other allergens, secondary pollutants can cause cardiorespiratory health effects. Also, climate change brings various problems like mental health problems, malnutrition, water-borne disease, and vector-borne illness, making the human population vulnerable to climate change.

Unchecked climate change will lead to extreme health impacts. The direct effects of climate change include deaths from thermal stress, injuries and fatalities from hurricanes, cyclones and storms, drowning in floods, etc., and indirect effects include infectious diseases transmitted through vectors(e.g., Cholera, malaria, etc.), water(e.g., diarrohea), food, etc. These direct and indirect impacts impact the population's livelihood, food security, water availability, agricultural yields, etc. So, one of the best responses to climate change may be a decrease in emissions of greenhouse gases(GHGs) which are one of the main reasons behind global warming. Also, manufactured chemicals like chlorofluorocarbon have been deteriorating the stratospheric layer and causing formation of holes in it. Suppose nothing is done to control the degradation of the ozone layer. In that case, the radiation of ultraviolet rays will increase on the earth's surface causing skin cancer and many more problems to human health.

The primary purpose of this paper is to provide examples of global issues and give possible suggestions regarding global climate change to protect public health and the global environment. In this paper, we have discussed climate change and its effect on the environment, the perspective of some countries concerning climate change, the effects of climate change on human health, the economic aspect of climate change and ways to tackle the possible situations. This paper would give people a better understanding of climate change and consider using more sustainable and energy-efficient devices to reduce energy consumption and prevent pollution.

1.1 Global Climate change and its impact on the environment

Anthropogenic-derived greenhouse gases are one of the major causes of global warming, which leads to global climate change, therefore directly or indirectly concerning public health. We can get an idea of global warming by measuring the levels of CO_2, as it represents about 63 % of the greenhouse gases (GHG). These greenhouse gases have already increased Earth's surface temperature by 0.80°C and are further expected to increase the atmospheric temperature by 0.20°C per decade [1].

In the year 1959, measurements of the changes in concentration of CO_2 began on Mauna Loa, Hawaii, which were initially 316 ppm, and since then, these concentrations

have been increasing. Presently the amount of CO_2 is around 419 ppm (fig. 1).

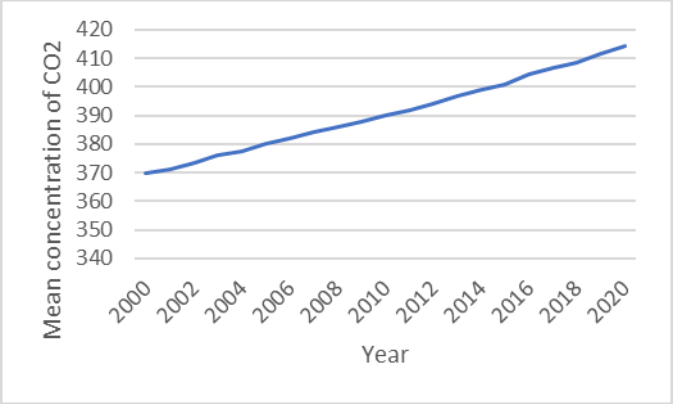

Fig -1: Trends in atmospheric CO_2 [2]

1.1.1 Heat waves

Heat stress will be one of the first consequences of global warming. This will result in increased temperatures in the daytime and also during the night, thus increasing mortality, especially in elders. Heat waves constitutes of two main features. The first feature, abnormally warm conditions imply abnormal high temperatures, which means that identical temperatures can have different effects at different locations or different times of the year, and prolonged exposure. The second, prolonged exposure, signifies the difference of heat waves from hot days that occur apart. Continuous exposure to heat waves for consecutive days can have adverse effects on public health, the performance of infrastructure, etc. [3].

1.1.2 Changes in precipitation pattern

Global warming may have a significant impact on the environment if no measures are taken. It has the potential to change snowfall and rainfall patterns. From recent researches, it is clear that there are about 90% chances that around 3 billion people worldwide will have to choose either to migrate to areas with milder climates or to go hungry as a result of global crop agricultural failure due to climate change which will be the consequence of shortage in the amount of precipitation.[4]

1.1.3 Melting of glaciers, sea ice and its impact on Biodiversity

The temperature in the Arctic has been rising twice the global rate, which has resulted in the melting of glaciers, sea ice, etc., at an alarming rate. It is estimated that 15-40% of the biodiversity will become extinct as a result of warmer conditions. Some of the world's iconic species of Arctic region, like polar bears, ringed seals, emperor penguins, and beluga whales, all experience distinct pressures due to melting sea ice.

The Greenland ice sheet is melting, thus increasing the sea level. If the ice sheet melts completely, it could increase the sea level by 23 ft. According to scientists, if the area warms by only a few more degrees, it could cause an unstoppable melting of ice sheets, thus resulting in flooding [4,5].

2. Global Climate Change, Air Pollution, and Global Warming

Global warming will play a significant role in Global climate change. This change will alter ambient temperatures, levels of particulate matter(PM), ambient allergens, and ozone which consequently will affect healthy lungs [6].

Considering that the quality of air and global climate change is directly linked to emission, it is clear that reducing the levels of GHGs, which is the primary source of global warming may improve air quality and reduce air pollutants, thus saving humans from possible adverse impacts of climate change [7].

The emission of nitrogen oxides (NO_X), methane (CH_4), and many other volatile organic compounds can combine in the lower atmosphere to produce ozone. This ozone present in the lower atmosphere is a hazardous pollutant. When consumed at high levels, it can cause adverse effects on human health, damage vegetation. Also, it is a GHG and can contribute to global climate change [7].

2.1 Climate Change, Indian Perspective

In 2019, the population of India faced PM concentration of about 91.7 $\mu g/m^3$. The northern part of India witnessed higher concentrations than the southern parts, and the total percentage of deaths reached around 10.4% in the country only due to Ambient Particulate matter pollution.

Ambient air pollution alone contributed to 11.5% of the total disability-adjusted life-years(DALYs) in the year 2019 [8]. Ambient particulate matter pollution accounted for 6.7%(5.3-8.0) of the DALYs, household air pollution accounted for 4.5%(3.0-6.7), and ambient ozone pollution accounted for 0.7%(0.3-1.0) of the total DALYs. Therefore, about 108.56 million people were affected because of air pollution. The northern states were the most affected ones with the highest rates of ambient particulate matter, which varied 5.5 times across states in 2019. The DALY rate for the northern and northeastern states was the highest for household air pollution, which varied 132.3 times across states in 2019. The DALY rate due to ambient ozone

Table 1

Deaths and DALYs caused due to air pollution in India in 2019 [8]

	Number of deaths, millions*	Percentage of total deaths	Number of DALYs, millions	Percentage of total DALYs
Air pollution	1.67(1.42-1.92)	17.8%(15.8-19.5)	53.5(46.6-60.9)	11.5%(10.2-12.8)
Ambient particulate matter pollution	0.98(0.77-1.19)	10.4%(8.4-12.3)	31.1(24.6-37.5)	6.7%(5.3-8.0)
Household air pollution	0.61(0.39-0.86)	6.5%(4.3-9.0)	20.9(14.1-28.7)	4.5%(3.0-6.1)
Ambient ozone pollution	0.17(0.08-0.26)	1.8%(0.9-2.7)	3.06(1.51-4.83)	0.7%(0.3-1.0)

pollution varied 11.2 times across states in India in 2019 in a diverse manner with regard to geographical location.[9]

Out of the total people had DALY in India due to air pollution(one of the major causes and result of global climate change) in 2019, 39.5% were from lung disease including COPD(22.7%), lower respiratory infections(15.5%) and 1.3% were from lung cancer. The rest of the DALY were from ischaemic heart disease(29.4%), stroke(13.7%), diabetes(5.5%), neonatal disorders(14.5%) and cataract(1.5%). Most of the deaths due to air pollution were due to COPD, ischaemic heart disease, and lower respiratory infections [9].

India faced deaths of 1.67 million people only due to air pollution, which is responsible for 17.8% of the total deaths. Ambient particulate matter resulted in death of 0.98 million (0.77-1.19) people, 0.61 million(0.39-0.86) deaths due to household air pollution and 0.17 million(0.08-0.26) died due to ambient ozone pollution(Table 1) [8].

2.2 Climate change, Australian Perspective

Global climate change has been affecting the whole Earth in some manner or the other. The Australian continent is surrounded by tropical, temperate, arid, and alpine climate regimes with high variability. From recent researches, it is clear that the temperature has been showing increase in warming, increased rainfall in tropical areas and decrease in rainfall in temperate areas. These trends may impact the biodiversity, agriculture, and infrastructure of that region negatively [15].

The Australian continent's atmospheric temperature has increased by 0.9°C from the year 1910 to 2011 [16] i.e., 0.2°C more than the global average temperature for the same interval. [17] The majority of the warming has been occurring after 1950 and with every decade, temperature has been warmer than that of the previous average [18].

Australia is the driest continent that is inhabited on Earth. It is vulnerable to relatively small changes in rainfall. Northwest Australia, Southwest Western Australia, Southeast Australia, and Northeast Australia witnessed significant changes in precipitation since the year 1900 and specifically in 1950 [19]. Higher atmospheric levels of aerosols that come from the continent of Asia enhance the cloud formation resulting in a long-term increase in annual rainfall in the summer months of northwest Australia [20,21,22,23]. A decline in rainfall has been observed in southwest Australia in past years. About 15% of the decrease in winter rainfall had been observed from the mid 1970s to 2007 [20].

Australia witnessed the record-breaking heatwaves in the year 2009, which caused extreme bushfires in the greater Melbourne metropolitan area [24]. Melbourne experienced its highest ever temperature, i.e., 46.4°C on February 7(also known as 'Black Saturday'). On this day, the bushfires started and took the lives of 173 people of the area [19,24].

It is now suggested that if no actions are taken to save our environment and stop climate change, then bushfires like this will happen more frequently.

2.3 Climate change, European Perspective

The climate changes in Europe accompanied by heat waves affected the respiratory health of the public. It can be seen from the data of August 2003, when more than 20,000 people died in England, France, Spain, Italy, and Portugal [10]. More deaths occurred in Moscow because of very high temperatures and forest fires in the year 2010. Due to changes in the global climate, there has been an increase in

the number of forest fires in the Southern part of Europe during the last few decades, resulting in an increase the PM concentration in the air during the dry season.

Climate change is causing flooding in almost every part of Europe. In the year 2013, the water from Donau caused damage of around 8 billion Euros in Germany, causing many other problems like humid conditions caused by the high-water table. At least 52,000 people had to evacuate during the June 2013 floods in Germany. Also, 8 people lost their lives in Germany, and the total number of fatalities in all the affected countries was 25 [11].

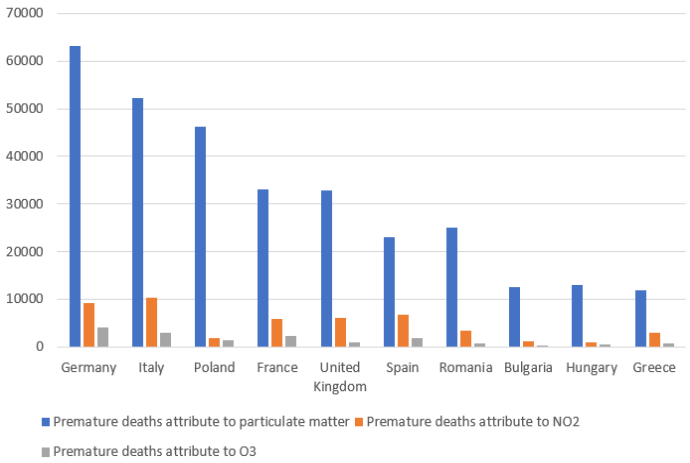

Fig -2: Premature deaths attribute to air pollution in 2018[14]

Ozone generation can occur around boreal forests as a result of higher temperatures. According to the Danish Eulerian Hemispheric Model(DEHM), the temperature-dependent biogenic emission will increase significantly over land[12]. As a result of greater ozone production along with increasing water vapour, the proliferation of free hydroxide radicals($^{\bullet}OH$) will be amplified which will consequently increase respiratory morbidity. A higher volume of pollen concentration can be a result of more extended pollen season. Pollen concentration may increase around 2-6 folds according to a Swiss study from 1979-1999, which would result in an increase in the number of allergic symptoms in the affected population [13].

The report of the European Environmental Agency of the year 2020 shows the number of premature deaths caused by air pollution. It is clear from the report that the number of deaths from PM was the most. The total number of premature deaths was 4,17,000 due to PM, 55,000 because of NO_2 and 20,600 because of O_3 in 2018 across the 41 European countries and the EU-28 according to the report [14].

Since Germany's population is the most among all EU countries, it faced the maximum number of deaths with a number of 63,100 premature deaths only because of over-exposure to PM [14].

3. Global Climate change, and its impact on Public Health

Global climate change is capable of threatening human health in many ways. Warming of average temperature only by 0.85°C has resulted in anticipated threats to become real impacts. These impacts can be of two types: First direct impact, which includes heatwaves, storms, forest fires, droughts, floods, etc. and second indirect impacts which occur due to change of climate on the ecosystem, e.g., Agricultural losses, changing patterns of disease, economies and social structure like migration, conflict, etc. The population of some regions is more vulnerable to climate change than others due to cultural norms, socioeconomic inequalities, improper management of public health systems, and various other factors [25].

3.1 Impact of heat waves on public health

The climate changes as the frequency of heatwaves increase [26]. Mortality is directly proportional to hot weather, especially in older people. Excessive heat waves can result in mortality due to cerebrovascular, cardiovascular, and respiratory causes. The number of premature deaths is higher in urban places because of an effect called the urban heat island effect. Here, the temperature is higher as compared to the surrounding sub-urban-rural areas [27].

Heatwaves also increase air pollution, which results in higher death rates. Europe is the best example that even high-income countries can face adverse effects in the absence of integrated and coordinate response, can cause a large number of deaths [27].

3.1.1 Tackling Heat Waves

To tackle heat waves, emergency measures like advice on behaviour, access to cooled spaces, etc. should be applied. Using air conditioners is not a good measure as it will only contribute to more levels of anthropogenic heat production and is also unsustainable. Instead, we can take better measures like cool paints, external shading, insulation of buildings. These are much more feasible as once installed, they require significantly less or almost no amount of energy to operate [28].

3.2 Impact of Storms, Floods and Droughts on public health

Global warming can cause extreme precipitation as the rise of only 1°C in atmospheric temperature can cause an increase in the proportions of saturation concentrations of atmospheric water vapor which supplies water for rain. Extreme precipitation will increase the frequency of flooding, which will cause economic loss, negative impact on terrestrial and aquatic ecosystems and human societies [29].

These disasters due to climate change will also have various health impacts, including physical injury, various diseases, mortality, and long-lasting effects on human mental health. In 1996, Biescas, Spain, saw a flood in town as a consequence of a stream of water and mud which covered a campsite near a channelized river causing death of 86 people [30]. River floods in central Europe left at least 2,00,000 people homeless and killed more than a hundred people. Flooding can also cause mobilizing of chemicals in the environment from industries, etc., such as pesticides. In the Meuse river, heavy metal soil contamination was found after the flooding. It had the potential to risk the health of riverbank inhabitants as the contaminated water washed the floodplain soils with excessive amount of lead and cadmium [31].

Floods increase the risk of diarrhoeal and respiratory diseases if took place in any country. A negative impact on the local economy is a major concern in industrialised countries as it may cause depression, mental disorders in the population, malnutrition, etc. Low-income countries are much more vulnerable as limited health infrastructure and harm to the local economy, and the national economy is proportionately higher than in industrialised countries [32].

Hurricane Katrina which is considered as the most expensive natural disaster in the US history) killed at least 1300 people, injured around 2000 people, and displaced over a million people [CDC web pages http://www.cdc.gov/].

Droughts occur when there is significantly less or no precipitation in a region. They have extensive effects on the health of the population. Infectious diseases, forest fires causing air pollution, nutrition are some of the effects on health caused to people due to droughts. El Niño cycle strongly influences the number of people who are affected by droughts [33].

3.2.1 Tackling these extreme events

To tackle extreme situations like storms, floods, etc., we should approach towards the improvement of early warning systems(EWS), do effective and efficient planning before we face such events and identify and track communities which are more exposed and vulnerable [40]. These EWS can include weather forecasting, possible health outcomes on vulnerable populations, pre-planning and executing effective and efficient strategies, and communication prevention responses [25].

The health authorities of the country should conduct emergency programs or disaster management programs and various exercise programs for its citizens to prepare them for any possible situation, both mentally and physically [25].

3.3 Impact of Infectious Diseases

Many infectious disease-carrying agents are climate - sensitive, and one the best examples of this type of disease is vector-borne diseases. They exhibit a seasonal pattern in accordance with temperature and rainfall. Malaria is an example of a vector-borne disease which shows variation almost every year in some regions which is due to climatic factors [34]. Various factors like temperature, altered rainfall, soil moisture, sea rise, humidity affect vector-borne illness transmission. These disease-causing pathogens require a host, a competent vector, and an adequate number of these pathogens to be present at the same time. As the global climate changes, it may cause an increase in the duration of transmission season in some regions. Many low-income countries are likely to be affected more due to these infectious diseases. It is assumed that the developed countries, which have controlled a deadly disease like malaria, etc., earlier may also control other diseases. In poorer countries, malaria is only restricted in arid and highland regions because of climatic reasons. In India, the distribution of malaria is expected to expand to higher altitudes. If the temperature increases in some areas, it would restrict malaria transmission in that particular area, resulting in more populations losing immunity and finally resulting in epidemics in later years [35]. Table 2 shows

Table 2

Examples of vector-borne diseases likely to be sensitive to climate change [26].

Vector	Major Diseases
Mosquitoes	Malaria, filariasis, dengue fever, yellow fever and West Nile fever
Sandflies	Leishmaniasis
Triatomines	Chagas disease
Ixodes ticks	Lyme disease and tick borne-encephalitis
Tsetse flies	African trypanosomiasis
Blackflies	Onchocerciasis
Snails (intermediate host)	Schistosomiasi

various vectors and diseases caused by them which are sensitive to climate change.

If global warming continues, it will increase the atmospheric temperature resulting in a warmer climate, resulting in more frequent water-borne diseases. These diseases include cholera, diarrhoeal diseases, e.g., giardiasis, salmonellosis and cryptosporidiosis [36]. Almost one fourth of the children in South Asia are affected by diarrhoeal morbidity. Increment in ambient temperatures, proliferation and various other factors lead to increase in widespread of this disease even further [37]. An example of a famous diarrhoeal disease is cholera. Cholera outbreaks have taken place in the following countries: India, Bangladesh, Latin America and Africa [38]. Recent researches have shown, increase in the sea surface temperature as an onset of cholera epidemics

with the outbreaks in following seasonal rise and fall with sea surface height and temperatures [38].

3.3.1 Tackling infectious diseases

Infectious diseases are one of the major concerns when we talk about climate change. If a disease widespread happens during any extreme event, it would be challenging to overcome it as it may become an epidemic and cause mass deaths. To tackle these infectious diseases, the government should start investing in public health. The health of the population can directly be determined from its education, health care, and public health prevention. Infrastructure can play a crucial role in determining the vulnerability and resilience of the population [41]. According to the UN Framework Convention on Climate Change(UNFCCC), total costs of health sector adaptation in developing countries should be around US$4-12 BN in the year 2030. If the public health sector does not invest in public health, consequences will be far more expensive than this investment. Also, adapting to climate change will not only reduce the impacts but also improve the population's immunity [42].

Another approach to tackle the widespread of infectious diseases is, one health approach, which is also the most sensible one. Collaboration across multiple disciplines and geographical territories to protect the health of people and environment is required in this approach. More than 70% of these diseases are caused by pathogens and also are linked to poverty [43]. A well-functioning national people health system, robust long-term funding, and reliable diagnostic together are an effective response to a spreading infectious disease. Outbreaks of these diseases cause a huge impact on the economy.

The World Bank provides no regret options as the investments will help in reduction in vulnerability across climate future. It also enhances strength by linking civil societies and government, giving early warning to respond to many disease risks [25].

When the Ebola epidemic took place in West Africa, it proved that strengthening the capacity of the countries to monitor and respond to the disease outbreaks is very important. So, the third approach which can be used to tackle infectious diseases is Surveillance and monitoring. The data and information can be collected by public health services and can be monitored by monitoring systems, after which this data can be used to determine the disease trends and burden, understand its pattern, identifying vulnerable communities and therefore prepare a response plan to tackle the situation [44].

4. Economic Aspect

Global climate change is not only affecting the lives of people but also threatening the global economy. Heatwaves have the potential to reduce the productivity of humans. Hurricanes, cyclones, typhoons, storms, etc., are responsible for making many people homeless, leaving them in absolute poverty. Droughts result in low harvest and therefore, minuscule amount of food to feed the population, which is increasing quickly and is expected to reach 10 billion by the year 2050 according to World Population Prospects 2019, United Nations Organisation. The World Bank warns that if something is not done immediately, then climate change may result in poverty of 100 million more by the year 2030. To solve this problem, we need private public sector collaboration and change the way of producing goods to drive sustainable economic growth.

If the average temperature increases by only 3.2°C, then China could lose 24% of its GDP by the mid-century, France or Greece could lose 13% of its GDP, Europe could lose around 11% of its GDP, the US, Canada, and the UK could suffer about 10% loss in GDP [38]. Figure 3 shows the percentage loss of GDP in various countries if their average temperature increases only by 3.2°C.

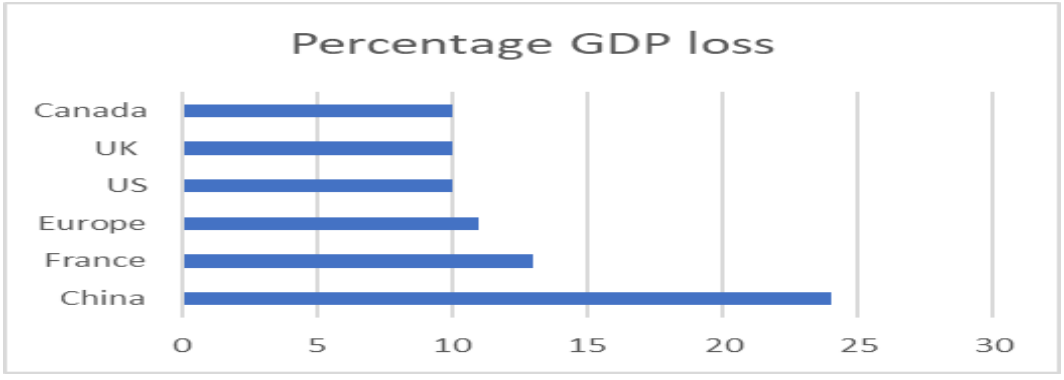

Fig -3: Percentage loss of GDP in various countries if their average temperature increase by 3.2°C [39]

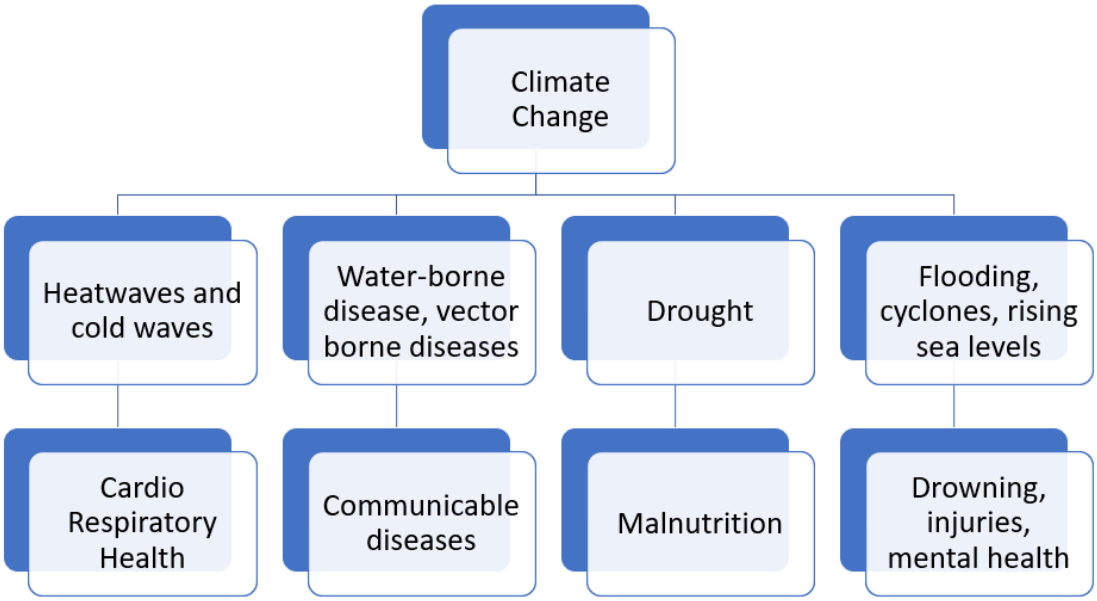

Fig -4: Impact of climate change on Environment and its effects on human health

According to a study conducted in the Swiss Re Institute, if nothing is done to stop climate change, then the world may lose up to 18% of the GDP. As we have already seen from past experiences that global warming impacts the weather-related natural disaster even worse, it implies that it will also substantially impact the income and impact productivity of countries. Let us consider an example of rising sea levels. As global warming increases, it would result in higher temperatures, resulting in melting of glaciers, sea ice, etc. which would finally increase the sea level. As the sea level rises, we will lose land which could have been used productively otherwise. Also, heat waves lead crop failure, and as the equatorial regions are the nearer to the sun, their emerging economies may be affected by rising temperatures [39].

5. CONCLUSIONS

There are still many more undiscovered aspects of potential threats to health due to climate change, and we, the people of twenty-first century need to work to improve our environmental conditions so that we can protect our precious environment and make our future world a better living place. We need a new model of human development that is sustainable and efficient, unlike present mode of development which is unsustainable and fails to provide basic needs for its people.

The expected health effects from the environment are to grow from many environmental processes. Various impacts may be caused due to changes in agriculture, natural resources, e.g., fresh water, insects, or vectors. Many ecological impacts of climate change will result in heat waves, change in precipitation patterns, melting of glaciers, and sea ice threatening the lives of the population on Earth. Figure 4 shows how change in climate impacts on environment and how those changes will impact human health. So, many scenarios based mathematical modelling can be used, which will give us an idea of the disease activity beforehand with the help of climate data i.e., derived from both computer and disease models to give both field and lab data.

Global warming causes in depletion of ozone gas in the stratosphere. It also causes various impacts on the environment like heat stress, vector borne diseases, respiratory diseases, allergic diseases, etc., and impacts developmental effects and many more. Thus, we need a much more global view, with regard to science and policy. We need to examine these phenomena and come up with sustainable and practical solutions like using less hot water, driving less and taking public transport instead, plant trees, stop using ACs with CFCs, etc.

With a continuously increasing population adapting to a constantly changing climate will be a difficult task. Since, we have limited resources on Earth, to achieve sustainability, we need human society to be in partnership between developed and developing countries that lack resources even for their basic needs, thus, benefitting each other. Also, we need to be prepared to face any challenge caused by global climate change as it will impact the economy negatively. Therefore, we should use more renewable resources and change the way of producing goods to a more sustainable and feasible

manner. A human society that values the environment and immediate human needs and needs of future generations will definitely progress.

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