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The Physics Behind Climate Change: Understanding Greenhouse Gases

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Abstract

Natural environments have a direct or indirect impact on all living things' well-being, growth, nourishment, and development. Globally, the main contributors to climate change include industrialisation, agriculture, urbanisation, and greenhouse effects. Every year, the earth's surface temperature and carbon dioxide (CO_2) levels rise due to these climatic changes. The primary goal of this review article is to study the effect of greenhouse gases in climate change. The pace at which the planet's temperature has increased over the last 50 years has deeply alarmed a number of scientists, engineers, and environmentalists. More flexibility in their adaptation will help plant species withstand fluctuations in the frequency of harsh weather occurrences. One of the factors causing climate change is GHG. The results show how climate change affects the environment, which usually shows up as rising temperatures and CO_2 levels.

Keyword: Climate change, Greenhouse gases, Greenhouse emissions, Fossil fuels, Renewable energy sources.

I. INT RODUCTION

Human health is significantly endangered by climate change. It impacts the physical environment, as well as the social and economic conditions and the functioning of health systems, in addition to all the aspects of natural and human systems. [1]. Therefore, it elevates the risk and has the capacity to revert decades of health advancements. Storms, droughts, floods, wildfires, and extreme heat waves are among the weather and climate events that are escalating in frequency and severity as climatic conditions vary. These weather and climate-related threats have an influence on health indirectly as well as directly by increasing the risks of noncommunicable diseases, infectious illness onset and death, medical emergencies, and transmission [2].

Climate change is having an influence on health sector personnel and infrastructure, which makes it more difficult to offer "universal health care (UHC)". The social and environmental factors of both physical and mental health are generally harmed by climatic disturbances and increasing pressures, such as fluctuating temperature and precipitation patterns, floods, droughts, and rising sea levels. [3]. Climate change affects numerous health variables, including access to pure soil, water, and oxygen, as well as food systems and livelihoods. By continuing to delay the resolution of climate change, we will undermine decades of progress in promoting global wellness, increase health risks, and violate our shared commitment to guaranteeing the right to optimal health for all. [4].

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A. The greenhouse effect

The balance of energy coming into and going out of the planet's system controls Earth's temperature. When sunlight hits the surface of the earth, it may either be consumed by it or projected back into space [5]. As the earth absorbs incoming energy, the globe warms up. Earth returns a portion of the energy to the atmosphere as heat, which is frequently referred to as infrared radiation, after it has been absorbed. Solar energy that is deflected back into space does not heat Earth [6]. Heat sent into space is slowed or stopped by particular gases in the environment absorbing energy. "Greenhouse gases" are the label given to these gases. As a result of their blanket-like nature, the earth experiences an increase in temperature. The "greenhouse effect," which is also known as this mechanism, is a fundamental and common component of the preservation of life. But the amounts of greenhouse gases in the atmosphere that humans are now causing have changed the climate of our planet and have dangerous effects on ecological systems, human wellness and welfare [7].

B. Greenhouse Gases: Composition and Characteristics

The Earth's temperature increases as a result of the fact that greenhouse gases capture heat in the atmosphere. The primary gases that contribute to the greenhouse effect are carbon dioxide, methane, nitrous oxide, and water vapour. Fluorinated gases that are chemically synthesised may also serve as greenhouse gases in addition to these organic materials. Distinct greenhouse gases are removed from the environment via distinct processes and possess unique chemical properties. For example, soil, the ocean, and forests are "carbon sinks" because they absorb carbon dioxide. Only in the upper atmosphere can sunlight destroy fluorinated gases [8]. Greenhouse gases have varied effects on global warming based on these primary factors:

- The quantity of gas contained inside the atmosphere. The concentrations are expressed in "parts per million (ppm), parts per billion (ppb), or parts per trillion (ppt)". For instance, a specific gas has a concentration of one part per million (ppm) in one molecule of air.
- A gas's lifetime is determined by how long it remains in the atmosphere.
- the amount of heat retention that the gas has. The term "global warming potential, or GWP", is the entire energy that a gas utilises over a specific period of time (typically 100 years) in relation to the emission of 1 tonne of carbon dioxide.

Through the greenhouse effect, the following gases are the most important contributors to global warming:

Carbon dioxide

Almost 80 percent of all emissions produced by people globally are carbon dioxide, which is a persistent gas. Forty percent remains in the atmosphere 100 years after discharge, twenty percent remains after one thousand years, and ten percent remains after ten thousand years. (Since carbon dioxide swings throughout the atmosphere, oceans, and land instead of destroying itself over time, its lifetime cannot be expressed in a single quantity. Certain carbon dioxide molecules are quickly absorbed by the atmosphere, while others remain there for many years.)

Methane

Compared to carbon dioxide, methane (CH_4) has a shorter atmospheric half-life of around 12 years, but it has a much stronger greenhouse impact. In actuality, its impact on global warming over a 100-year span is more than 30-fold greater than carbon dioxide's, pound for pound. According to projections from the United States. "Environmental Protection Agency (EPA)", In 2021, methane constituted approximately 12% of the greenhouse gas emissions that were caused by humans in the country. While wetlands and other natural sources may produce methane, human activities like the production of natural gas and livestock-based agriculture account for more than half of all methane emissions worldwide.

Nitrous oxide

N_2O, a potent greenhouse gas, has a "global warming potential (GWP)" that is approximately 270 times greater than that of carbon dioxide over a 100-year period. Its normal atmospheric half-life is little over a century. Emissions of greenhouse gases produced by people in the United States, including fertilisers used in agriculture, account for about 6% of total emissions, according to estimates from the Environmental Protection Agency.

Fluorinated gases

Fluorinated gases are produced by humans and are released from a range of industrial and manufacturing operations. The four main types are “perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), nitrogen trifluoride (NF_3), and sulphur hexafluoride (SF_6).”

C. Molecular Interactions and Radiative Forcing

Molecular interactions are the forces that pull non-bonded atoms and other molecules in one direction or another. Molecular interactions are essential to many parts of chemistry, biochemistry, and biophysics, including "protein folding, drug design, pathogen detection, materials science, nanotechnology, separations, and the origins of life". Other names for molecular interactions include noncovalent contacts, intermolecular forces, non-bonding interactions, and noncovalent interactions. These five expressions all have the same meaning [9]. A second method for quantifying greenhouse gases and other climatic variables, including the luminosity of the sun and large volcanic eruptions, is radiative forcing (RF). The gap between the quantity of "solar radiation" that the planet receives and the amount that is sent into space as a result of a particular “climate driver” is known as radiation forcing, or RF. A positive RF value for a climate driver indicates an earthly warming influence; a negative value indicates a cooling effect [10].

D. Uncertainties in Climate Science

Because trustworthy instrumental data span just a tiny area of the world during the last century or two, the historical record of global climate change is questionable. Nonetheless, it is probable that during the last century, global temperatures have fluctuated more than they did over the previous millennium [11]. The rate of ocean heat absorption, the response of the climate to rising greenhouse gas concentrations, and the effects of aerosols and cloud cover are all inadequately monitored, which casts doubt on projections about the amount of global warming that will occur in the twenty-first century [12]. There are still unknown elements that might effect climate in the future, such as the amount of methane in the environment and solar output. The uncertainty surrounding future sea-level changes is exacerbated by the difficulty to predict precipitation on Antarctica and evaluate the stability of the West Antarctic and Greenland ice sheets [13]. The world's population is expanding, there is economic and technical advancement occurring, land-use changes are changing, and efforts to stop the rise in concentrations of greenhouse gases in the environment are not always effective. These are examples of anthropogenic impacts. Predicting regional climate changes is considerably more challenging than global ones. Without a doubt, they will include more deviations from the long-term strategies in use now than from global shifts [14].

II. LITERATURE REVIEW

(Manabe, 2019) [6] Climate models have emerged as the most effective instrument for comprehending and forecasting climate change. Using a sequence of climate models that increase in complexity, I examine the function of greenhouse gases, such as carbon dioxide and water vapour, in global warming.

(Cassia et al., 2018) [7] Greenhouse gases (GHG) include “ozone (O_3), carbon dioxide (CO_2), methane (CH_4), nitrous oxides (NxO), and water vapour”. These gases are responsible for the greenhouse effect. The main causes of ROS under stress include increased photorespiration, β-oxidation of fatty acids, NADPH oxidase (NOX) activity, and anomalies in "the electron transport chains" of mitochondria and chloroplasts. NO controls the levels of ROS while maintaining the equilibrium between “ROS, GSH, GSNO, and ASC”. Significant concentrations of ROS cause NO to stimulate SOD, APX, and CAT transcription and activity. On the other hand, when ROS are needed (for instance, for disease resistance), NO may preferentially decrease "APX, CAT, and NOX activity" by S-nitrosylating cysteine residues. Additionally, NO controls GSH concentration in a number of ways. The primary source of S-nitrosylation and the reservoir for NO cells, GSNO, is created when NO reacts with GSH. GSNO reductase (GSNOR) may break down GSNO into GSSG, which is then reduced to GSH by glutathione reductase (GR). S-nitrosylation has the potential to inhibit GSNOR, whereas NO may activate GR. To sum up, NO is essential to plants' ability to adapt to climate change.

(Kweku et al., 2018) [8] The implications of the greenhouse gas research report for global warming. Because it reduces the average global temperature of Earth, the greenhouse effect impedes the existence of life on Earth. Among the greenhouse gases are nitrous oxide (N2O), CO2, water vapour, and methane. In order to prevent infrared light from dispersing into space, carbon dioxide (CO2) and other greenhouse gases absorb it, adhering to it like a blanket. Global warming is the obvious result of greenhouse gas concentrations steadily raising Earth's surface and atmosphere. One of the biggest mysteries in the field of environmental sciences is the ability of certain gases, referred to as "greenhouse gases", to be both transparent to arriving sunlight and opaque to energy released by the planet. The planet is a pleasant location for life because of the greenhouse effect. The research also highlights how crucial greenhouse gases are to Earth's warming.

(Abouelfadl, 2012) [4] The danger of global warming causes continual, serious damage to Earth's environment. Every 10 years, there has been a 2.7% decline in the quantity of Arctic Sea ice. The vast majority of people are still unaware of global warming and don't anticipate it becoming a significant problem very soon. most since 1978. Many people are ignorant of the fact that "global warming" is happening currently and that some of its terrible effects are already being experienced. The disturbance of ecological equilibrium will have a detrimental impact on ecosystems. The hazardous effects of global warming necessitate the development of specific solutions. The article elucidates the origins and hazards of global warming and proposes potential solutions to this pressing issue. It is crucial to conduct a comprehensive examination of alternative energy sources, including "wind, solar, hydro, geothermal, and biomass." One effective strategy for mitigating the ever-increasing effects of global warming is to identify and utilise renewable energy sources.

(Gabric, 2023) [15] These many crises, which affect various ecological, human health, and economic contexts, have been extensively recorded. Given the breadth and severity of CC effects, the comparatively benign phrase "global warming" has gradually given way to the more concerning classification of a "climate emergency" in expert nomenclature for the issues. Decades of inaction on the part of the government, conflicting scientific views, political conservatism and denial, as well as general public ignorance or apathy, have all contributed to the failure of serious attempts to confront ACC, despite calls for drastic societal change. There is little sign that the atmospheric concentrations of greenhouse gases will soon stabilise in the interim. Future prospects for ecosystems on Earth and the humans who depend on them are dire, with the impacts of ACC manifesting sooner than expected. Though they are now the subject of intense discussion in the scientific community, proposals to geoengineer the climate may end up being the final option if the effects of unchecked warming worsen.

(Kabir et al., 2023) [16] These climatic variations cause an annual increase in (CO_2) levels and the temperature of earth's surface. A number of environmental issues are being brought on by the daily rise in earth's temperature due to growing "carbon dioxide concentrations and global warming". This review's goal is to draw attention to climate change, which usually happens when temperatures increase and CO_2 concentrations rise, as well as its effects on the ecosystem. This climatic change is detrimental to ecosystems rather than helpful. The environment is thereby being negatively altered by human activity. Life has been impacted by growing climatic changes in a variety of ways. It is determined that in the next several years, living on Earth won't be simple, and things will go out of control if we don't develop the ways to deal with these changes.

(Thomas, 2020) [17] Climate change is the term used to describe significant variations over several decades in precipitation, temperature, snowfall, or wind patterns. It is a severe problem that is already affecting both the environment and people worldwide. A deeper understanding of the factors contributing to climate change benefits model simulations, theoretical investigations, public education, and feedback loops. Disseminating knowledge regarding appropriate and advantageous adaptation and mitigation options to professionals and policy makers is helpful. As a result, desktop data analysis and a variety of secondary data sources were consulted to compile this piece. As a result, a variety of factors, including human activity and natural processes, contribute to climate change. However, a number of studies have shown that human activity is mostly to blame for the causes of climate change in the modern age.

III.CONCLUSION

The continuous alteration of the precipitation patterns those tropical regions experience is known as climate change. Furthermore, researchers are starting to feel the impact of this worldwide challenge. Due to economic and social progress, humans are becoming more and more reliant on energy, and fossil fuels are now the only feasible supply. The petrol emissions that come from burning fossil fuels are the greenhouse effect’s main cause. The loss of habitat on Earth's surface will worsen due to rising CO_2 concentrations and rising temperatures, which are major issues that will spiral out of control. Global warming poses a significant risk, and adequate action must be done to address this pressing issue. This issue is not limited to humans; it is also producing problems for plants and animals. Based on the study, it can be concluded that greenhouse gases produced are highly toxic and despite various strategies, we failed to control it. This demands for novelty in the methods and more importantly, new laws and regulations for industrial sector. Proper implementation of such strategies can help in reduction of greenhouse gases on huge level and prevent the planet from global warming.

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