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# The Earth is Heating Up: Causes, Effects, and Solutions of Global Warming

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**Keywords:**
Global Warming,
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**Abstract:** Global warming is currently emerging as a significant cause for concern worldwide. With the increase in atmospheric greenhouse gases, significant changes in the Earth's climate balance are occurring, leading to various environmental and economic issues. Effects such as the intensification of heat trapped during the passage of solar radiation through the atmosphere, rising sea levels, and increased frequency of extreme weather events are among the direct consequences of global warming. In this article, we will delve into the causes, effects, and possible solutions of global warming. Initially, we will briefly explore the fundamental concepts of global warming and the role of greenhouse gases in the atmosphere. Subsequently, we will examine how human activities and industrialization affect the increase of greenhouse gases in the atmosphere. Additionally, we will focus on the effects of global warming, evaluating its potential consequences on natural systems and human life. Finally, we will provide some recommendations for environmental policies and measures that could be taken to combat global warming. This article aims to serve as a starting point for understanding the complex and multifaceted nature of global warming. In the following sections, we will delve deeper into the topic to gain a better understanding of the complexity and severity of global warming. In conclusion, global warming is a complex problem with a multifaceted solution. Even though the challenges are great, if we act determinedly and collectively, we can achieve solutions. An approach that makes sustainability transparent and takes a long-term perspective can lead to a healthier planet and a safe life for future generations.

# Dünya Isınıyor: Küresel Isınmanın Nedenleri, Etkileri ve Çözümleri

**Anahtar Kelimeler:**
Küresel Isınma,
İklim Değişikliği,
Fosil Yakıtlar.

**Özet:** Küresel ısınma günümüzde dünya genelinde ciddi bir endişe kaynağı olarak karşımıza çıkmaktadır. Atmosferdeki sera gazlarının artmasıyla birlikte, yeryüzündeki iklim dengesinde önemli değişiklikler yaşanmakta ve bunun sonucunda çeşitli çevresel ve ekonomik sorunlar ortaya çıkmaktadır. Güneş ışınlarının atmosferden geçişi sırasında tutulan ısının artması, deniz seviyelerinin yükselmesi, aşırı hava olaylarının sıklığının artması gibi etkiler, küresel ısınmanın doğrudan sonuçları arasında yer almaktadır. Bu makalede, küresel ısınmanın nedenleri, etkileri ve olası çözümleri ele alınacaktır. Başlangıç olarak, küresel ısınmanın temel kavramlarına ve atmosferdeki sera gazlarının rolüne kısaca göz atacağız. Sonrasında, insan faaliyetlerinin ve sanayileşmenin atmosferdeki sera gazlarını artırma sürecine nasıl etki ettiğini inceleyeceğiz. Bununla birlikte, küresel ısınmanın etkileri üzerinde durarak, doğal sistemler ve insan yaşamı üzerindeki potansiyel sonuçları değerlendireceğiz. Son olarak, küresel ısınmayla mücadelede alınabilecek önlemlere ve çevresel politikalara yönelik bazı öneriler sunacağız. Bu makale, küresel ısınmanın karmaşık ve çok yönlü doğasını anlamak için bir başlangıç noktası olmayı amaçlamaktadır. İlerleyen bölümlerde, konuyu daha derinlemesine ele alarak küresel ısınmanın karmaşıklığını ve ciddiyetini daha iyi anlayacağız. Sonuç olarak, küresel ısınma, çok yönlü bir çözüm, karmaşık bir sorundur. Zorluklar büyük olsa da kararlı ve ortak bir şekilde hareket ederse, çözümlerimizi ortadan kaldırabiliriz. Sürdürülebilirliği şeffaflaştıran ve uzun vadeli bir bakış açısı benimseyen bir yaklaşım, daha sağlıklı bir gezegen ve gelecek nesiller için güvenli bir yaşam sağlamanın yolunu bulabilir.

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## 1. INTRODUCTION

The Earth's atmosphere consists of various gases. Solar rays pass through the atmosphere to heat the Earth's surface. Gases like $CO_2$, $CH_4$, $N_2O$, $O_3$, and CFCs (chlorofluorocarbons) in the atmosphere trap some of the heat from the sun, thus maintaining the Earth's surface at certain temperature levels. The ability of the atmosphere to retain heat prevents the freezing of oceans and seas. This warming and heat-trapping property of the atmosphere is known as the greenhouse effect (Güçlü, 2006).

Since the end of the 18th century, with the onset of the Industrial Revolution and especially from the 1950s onwards, the rapid increase in human activity and the release of significant amounts of $CO_2$, $CH_4$, $N_2O$, and other gases into the atmosphere by industrial systems have led to an excessive greenhouse effect. This has caused a gradual increase in temperature on Earth's surface (in the lower part of the atmosphere, known as the troposphere). Human activity has been present on Earth since its appearance, even before the Industrial Revolution. However, these activities never reached the scale to create an event like global warming. The effect of greenhouse gases on the emergence of Earth's temperature and climate is of undeniable importance. Greenhouse gases trap some of the incoming and reflected rays from the sun, helping to maintain the Earth's surface at temperatures suitable for humans and other living organisms. It is estimated that if greenhouse gases were not present in the atmosphere, the average temperature on Earth would be 33°C colder than it is today. Especially in the last 30 years, the increase in greenhouse gas emissions into the atmosphere, triggered mainly by technological advancements, excessive fuel consumption, and population growth, has led to the continuation of the effects of global warming due to reasons such as the thinning of the ozone layer (Appenzerler and Dimick, 2004).

Global warming is not just about the gradual increase in temperatures worldwide. It involves the occurrence of extreme heat in one region leading to the rapid spread of forest fires, increased desertification, and even endangering human life. Simultaneously, in another part of the world, excessive rainfall leads to widespread flooding, the occurrence of flood disasters, and extreme erosion events (Appenzerler, 2006).

Global warming also leads to the gradual melting of glaciers accumulated in the polar regions and high mountains. Consequently, with the rise in sea levels proportional to the melting of glaciers, countries with land below or at sea level, such as the Netherlands, Belgium, Denmark, and Germany, may gradually face the invasion of seas, triggering numerous natural disasters (Lopatto, 2013).

## 2. MATERIALS AND METHODS

### 2.1. Materials

This study was conducted to investigate the effects of air pollution and climate change on health worldwide. Data sources included reports from the World Health Organization, climate science research, academic studies, articles published in scientific journals, and reports from various health organizations. A comprehensive literature review was conducted to determine the impacts of air pollution and climate change on children's health.

### 2.2. Methods

The methodology of this study is based on the analysis of existing scientific literature to assess the effects of air pollution and climate change on health. The literature review involved examining published research to identify the effects of air pollution and climate change on children's health. The focus areas of the research included low birth weight, respiratory diseases, neurological disorders, cognitive development, and the impacts of climate change on children's health. Compilation and analysis of existing data were used to understand the effects of air pollution and climate change on children's health. This study aims to provide fundamental knowledge to understand the effects of air pollution and climate change on children's health and to improve public health. A multidisciplinary approach, encompassing both qualitative and quantitative research methods, is required to analyze the effects of greenhouse gases on global warming and its consequences. This analysis will focus on examining historical data, scientific literature, and various models used to understand the impact of human activities on the Earth's climate system.

### 2.3. Scientific Literature Review

A systematic review of peer-reviewed articles, books, and reports published by climate scientists focusing on the greenhouse effect, global warming, and their consequences on the environment. This will include studies on $CO_2$, $CH_4$, $N_2O$ and other related gases.

### 2.4. Case Studies

Analysis of specific regions affected by global warming, including both positive and negative impacts such as temperature increase, desertification, flooding and glacial melting. Particular attention will be paid to regions such as the polar regions, the Netherlands and other low-lying countries.

### 2.4. Analytical Techniques

#### 2.4.1. Trend analysis

The use of statistical techniques to examine trends over time in temperature changes, greenhouse gas emissions, and associated impacts such as glacier melt, sea level rise, and extreme weather events. This analysis will highlight the relationship between human activity and observed changes in Earth's climate.

#### 2.4.2. Comparative analysis

Comparison of climate data from regions heavily affected by global warming (e.g. polar regions) with less affected regions to assess broader impacts for global weather patterns and ecosystems.

## 3. RESULTS AND DISCUSSION

### 3.1. The History of Global Warming

Since humans began spreading from the African continent to Asia and Europe, starting some 1.8 million years ago according to some, and 1.6 million years ago according to others, there have been several glacial periods and interglacial periods. These periods include the Günz (1.8 million-750 thousand years), Mindel (500-300 thousand years), Riss (250-130 thousand years), Würm glaciations (70-10 thousand years), and the interglacial periods between them: GünzMindel (750-500 thousand years), Mindel-Riss (300-250 thousand years), Riss-Würm (130-70 thousand years), and the post-Würm glaciation period (from 10 thousand years ago to the present). These glacial periods and interglacial periods on Earth have occurred due to various factors such as the Earth's movement around the Sun, tectonic movements, and volcanism, leading to periods of extreme warming and cooling on Earth. Many plant and animal species became extinct during these extraordinary periods, while new species emerged. Thus, observed extraordinary climate changes led to the disappearance of species unable to adapt to these conditions, while also facilitating the development of new species adapted to environmental conditions (Açıkkol, 2006)

Furthermore, since the end of the Mesolithic period (approximately 10 thousand years ago) when humans began to transition to a settled lifestyle, the world's climate has followed a relatively stable course. Due to the lack of significant changes in recent history, we may assume that there have been no significant climate disasters or changes since the emergence of life on Earth. However, data from the science of paleoecology actually indicate that the Earth's climate system has not remained at a constant level. In short, from its formation, the Earth has experienced periods of warming and cooling several times. These events occurred within the natural cycles and conditions of nature. However, global warming is a phenomenon entirely different from past climate changes, as it is a direct result of human activity (Appenzerler and Dimick, 2004; www.cevreorman.gov.tr; 2003).

Greenhouse Gases and Their Characteristics Leading to Global Warming: Global warming is the rapid increase in the levels of greenhouse gases in the atmosphere due to human activities. The increase in human activities since the Industrial Revolution, the rapid spread of technology, and efforts to raise living standards have led to an excessive increase in the amount of greenhouse gases in the atmosphere. Especially since the second half of the 20th century, the rapid increase in greenhouse gases has led to the onset of natural disasters threatening the lives of plants, animals, and humans. According to a study by the Ministry of Environment and Forestry, human contributions to global warming include 49% from energy consumption, 24% from industry, 14% from deforestation and destruction of forests, and 13% from agricultural activities. Other studies have also found that human energy consumption has the highest impact on global warming (Bozoğlu and friend, 2003; www.cevreorman.gov.tr).

Solar rays, particularly energy-rich infrared rays, returning to space from the atmosphere after reaching the Earth's surface, are prevented by greenhouse gases, leading to global warming. As the concentration of greenhouse gases in the atmosphere increases, their greenhouse effect also increases. The most prominent greenhouse gases in the atmosphere are Carbon Dioxide ($CO_2$), Methane ($CH_4$), Nitrous Oxide ($N_2O$), Ozone ($O_3$), Carbon Monoxide (CO), and Halocarbons (such as CFCs). Additionally, water vapor is also considered a greenhouse gas.

Carbon Dioxide ($CO_2$): It accounts for 82% of greenhouse gases. Although the amount of $CO_2$ in the atmosphere has remained unchanged for millions of years, it has increased by 31% since the beginning of the Industrial Revolution. While the annual increase in atmospheric $CO_2$ was 0.4% in the 20 years before 1990, it varied between 0.2% and 0.8% in later years. The majority of $CO_2$ released into the atmosphere is derived from widely used fossil fuels (Bozoğlu ve ark, 2003; Türe, 2003).

Methane ($CH_4$) Gas: It is the second most significant greenhouse gas after $CO_2$. Its quantity has increased by 151% since the beginning of the Industrial Revolution and continues to rise. There has been a slight decrease in methane emissions since 1990. Nearly half of the current methane emissions come from human activities such as the use of fossil fuels, waste disposal, animal husbandry, and rice cultivation (Kadioğlu, 2001).

Nitrous Oxide ($NO_2$) Gas: It has shown a 17% increase since the Industrial Revolution. Approximately one-third of nitrous oxide emissions into the atmosphere occur during the use of agricultural land, chemical industry processes, and the production of livestock feed. The amount of $N_2O$ in the atmosphere is increasing (Bozoğlu ve ark, 2003; Karakaya ve Özçağım, 2004).

#### 3.1.1. Climate change

Throughout the approximately 4.5 billion years of Earth's history, there have been significant climate changes at various periods due to disruptions in the natural balance among its elements. However, the most well-known climate changes occurred during the Quaternary period. Until the emergence of humans, the geography of the Earth underwent numerous changes (Figure 1). These changes resulted from disruptions in the relationships among the components of the climate system: the sun, atmosphere, and Earth, through natural mechanisms. It is necessary to attribute the climate changes that occurred from the emergence of humans to the Industrial Revolution to natural causes. Since the mid-19th century, it is evident that human influences have contributed to changes previously associated with natural factors (https://climate.nasa.gov).

Indeed, during the period from the emergence of humans to the present day, both the natural and human environments have been significantly affected by the presence of "glacial" periods when the Earth's surface was covered with ice, as well as interglacial periods when glaciers retreated. For instance, about 20,000 years ago, cold temperatures affecting the northern hemisphere led to complete coverage of the northern regions of Europe with glaciers and a decrease in sea levels by 125 meters compared to today. As a result of the sea level drop, Siberia and Alaska merged into a single landmass. This environmental change facilitated the migration of humans

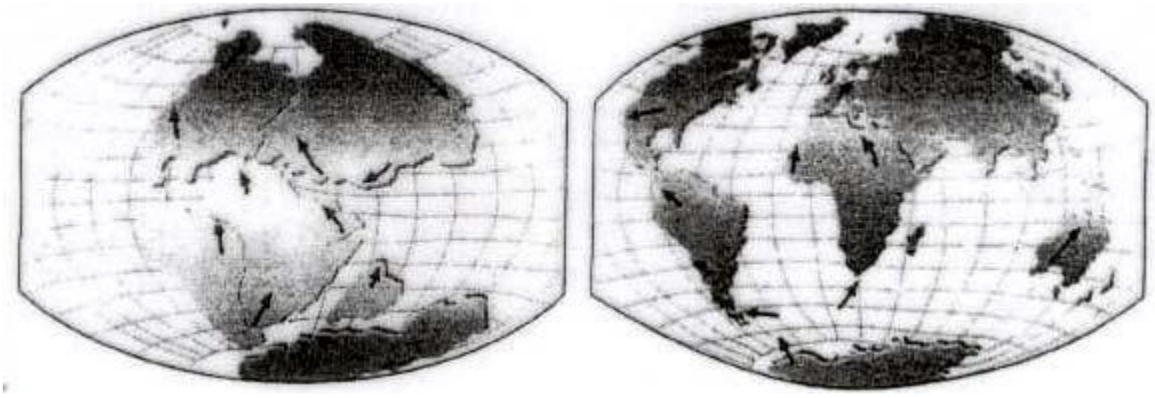

**Figure 1.** Distribution of continents 180 million years ago and today. (Woods Hole Oceanographic Institution's Dive & Discover project provides information on the processes of Pangea breakup and plate tectonics, including animations showing continental drift over millions of years:contentReference[oaicite:0]{index=0}:contentReference[ oaicite:1]{index=1}).

and plants from Asia to the Americas. Therefore, it is claimed that Native Americans have Asian origins. This period lasted for about 4,000 years, after which glaciers began to retreat and temperatures started to rise again (Ahrens, 1994).

Around 11,000 years ago, temperatures rapidly dropped, and once again, the northern regions of Europe and the northeastern United States were covered with glaciers. About a thousand years after this glacial advance, temperatures gradually began to rise again, and about 8,000 years ago, the glaciers that covered the land completely disappeared (https://www.ncei.noaa.gov/products/paleoclimatology).

Around 6,000 to 6,500 years ago, the global average temperature was one degree higher than today. This period, known as the "Mid-Holocene Maximum" was a time when plants flourished, various ecosystems formed, and the Earth approached its current climate position. In the following years, a general cooling trend was observed, resulting in the formation of glaciers on some mountains such as the Alpine glaciers, and the northern hemisphere reached its present appearance (Cambell, 1995).

Within the last thousand years, the climate conditions in the northern hemisphere can be summarized as follows:

I. In the 1200s, a temperate but variable climate type was prevalent. Natural disasters such as storms, floods, severe rainfall, and droughts occurred over several centuries.

II. Between 1400 and 1550, stable climatic conditions prevailed. From the mid-1550s onwards, a period known as the "Little Ice Age" occurred, lasting for 300 years. During this period, mountain glaciers advanced into valleys, and short and rainy summers were observed.

III. During this period, abnormal climatic conditions occurred in 1816, resulting in a severe famine in Europe, causing the loss of many human and animal lives due to hunger. Significant cold temperatures were experienced between May and September in the United States and Canada, with 1800 people freezing to death during this summer period. This period is referred to as the "year without a summer."

IV. From the late 1800s to the 1940s, the global average temperature increased by about 0.5 degrees Celsius. This increase was followed by a cooling period of 25 years.

V. In the 1970s, 1980s, and 1990s, a trend of increasing global average temperatures was observed. The hottest eight years occurred after 1978 in the 1990s.

VI. The year 1998 was the hottest year since measurements began with instruments in both the northern and southern hemispheres in 1860.

Today, in addition to natural factors, it is acknowledged that disturbances in the climate system are also due to various human impacts. Climate change is defined as "a change in climate that is attributable directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods" (Intergovernmental Panel on Climate Change, IPCC).

### 3.1.2. Global warming and some uncertainties

Since the Industrial Revolution, there has been a noticeable trend of increasing average surface temperatures due to the accumulation of greenhouse gases, primarily $CO_2$, as well as other greenhouse gases (methane - $CH_4$, nitrous oxide - $N_2O$, chlorofluorocarbons - CFCs, etc.), which trap outgoing longwave radiation from the Earth's surface. Indeed, there has been a 0.8°C increase in global temperatures over the past century (Roberts, 2013).

The greenhouse effect, which is primarily responsible for global warming, occurs when a portion of the incoming solar radiation is absorbed by the Earth's surface and re-emitted as long-wave radiation. While some of this radiation is directly released into space by the atmosphere, a significant portion is absorbed again by the atmosphere. Short-wave solar radiation is highly transparent to atmospheric gases, whereas, due to the accumulation of greenhouse gases, the atmosphere becomes less transparent to long-wave radiation emitted from the Earth's surface. As a result, the lower layers of the atmosphere experience more warming than would be expected, leading to the phenomenon known as the greenhouse effect (Açıkkol, 2006).

I. 51% of the short-wave radiation from the Sun is absorbed by the Earth's surface, warming it.

II. Some of the energy absorbed by the Earth's surface is radiated back into the atmosphere.

III. Some of the solar energy is reflected back to space from the atmosphere without reaching the Earth's surface.

IV. A portion of the energy emitted from the heated Earth's surface is released into the atmosphere as long-wave radiation. Some of this energy is absorbed by greenhouse gases in the atmosphere, heating the lower layers. This heating is the greenhouse effect.

V. Some of the energy absorbed by greenhouse gases is re-radiated back into space.

VI. Some of the energy emitted from the Earth's surface goes directly into space.

### 3.1.3. The effect of carbon dioxide ($CO_2$) and other greenhouse gases

Among the greenhouse gases that have an impact on global warming, carbon dioxide ($CO_2$) holds a distinct place and importance. Carbon dioxide ($CO_2$) is a significant greenhouse gas in warming the lower atmosphere since it largely allows short-wave solar radiation to pass through but absorbs long-wave radiation emitted from the Earth's surface. As is known, the amount of carbon dioxide in the atmosphere is rapidly increasing primarily due to the various uses of fossil fuels. Additionally, deforestation, particularly the extensive destruction of tropical rainforests, and the replacement of forest cover in other regions with new vegetation also contribute to this increase. Studies indicate that the amount of carbon dioxide emitted into the atmosphere annually was around 355 ppm (parts per million) at the end of the last century and could double in the present century. Mathematical climate models suggest that this doubling of $CO_2$ levels could lead to an average temperature increase of between 1.5 to 4.5 degrees Celsius by the year 2050. However, such studies also reveal uncertainties. If deforestation is considered the primary cause of the increase in carbon dioxide rather than the use of fossil fuels, the amount of $CO_2$ and consequently the value of global warming may be lower than estimated. Additionally, another uncertainty highlighted by model studies is the incomplete understanding of the mechanisms associated with the transportation of carbon dioxide from the atmosphere to other environments. Moreover, it is necessary to consider the concentrations of other greenhouse gases, such as methane ($CH_4$), nitrous oxide ($N_2O$), and chlorofluorocarbons (CFCs), which absorb infrared radiation and contribute to the greenhouse effect along with carbon dioxide. In addition to this, climate models indicate that with the increase in global temperature, ocean temperatures will also rise, leading to increased evaporation. As a result, more evaporation will occur, accelerating the warming effect of water vapor, which is one of the most important greenhouse gases in the atmosphere (positive feedback). Model studies that only consider the doubling of the current carbon dioxide levels without taking into account this input of water vapor suggest that the increase in global average temperature would be around 1 to 2 degrees Celsius (Gakidou et al, 2017).

### 3.1.4. The effect of oceans and clouds

Undoubtedly, the oceans, which cover two-thirds of the Earth's surface, play a significant role in the climate system. However, the exact effects of the oceans, which are a massive reservoir for carbon dioxide, on observed and potential global warming have not been fully elucidated. Some researchers argue that carbon dioxide used during carbon assimilation by small (microscopic) plants living in the oceans is returned to ocean waters with the death of these plants and is mixed into the atmosphere with unexpected warming in ocean waters. They even suggest that the increase in atmospheric carbon dioxide levels in the last century was mainly due to this source rather than the use of fossil fuels. On the contrary, scientists argue that these plants continuously reproduce and proliferate, thereby reducing atmospheric carbon dioxide levels by utilizing carbon dioxide and causing a decrease in carbon dioxide levels.

Moreover, oceans are a vast heat sink that absorbs solar energy. As they slowly warm, the atmosphere shows a global-scale effect that reduces and delays global warming, as indicated and predicted on a global scale. Additionally, considering ocean circulations and sea ice in the context of possible climate change, as modeled in recent years, is essential. Studies on this topic demonstrate significant changes in ocean circulations during glacial and interglacial periods, indicating that they are very different from today's conditions. Indeed, recent climate model studies have shown an increase in average global temperature on a global scale while demonstrating that the cold ocean currents around Antarctica have not led to an increase in temperature in that region. These model studies even suggest that even if the carbon dioxide level were to quadruple, there would be no warming in these areas. These predictions and scenarios are generally accepted as they confirm previous studies. However, as research progresses within the highly complex climate system, it is essential to recognize that many more factors could be revealed as surprises. Additionally, the increase in atmospheric water vapor due to ocean warming will increase cloudiness on a global scale. This increase will undoubtedly have a significant impact on the climatic system. Clouds reflect some of the short-wave solar radiation back into space, reducing global temperatures. However, they also absorb long-wave radiation emitted from the atmosphere and Earth's surface, contributing to warming. Therefore, how will climate be affected by the increase in cloud cover? Probably, this situation is related to the type and structure of the clouds (their shapes, physical properties, formation from liquid and ice, and distribution of cloud droplets, etc.). For example, high cirrus clouds made of ice crystals have a warming effect, while low stratiform layer clouds have a cooling effect.

Cirro form type clouds, because they consist mostly of ice crystals, allow shortwave radiation to pass directly to the Earth's surface and absorb longwave radiation emitted from the ground (absorb), thus contributing to global warming. In contrast, stratiform type clouds, formed mostly of water droplets, reflect shortwave radiation back into space without allowing it to reach the ground. Additionally, since their top temperatures are relatively warm, they emit a significant

portion of the energy they receive from the ground back into space. Therefore, these types of clouds have a significant cooling effect. Satellite images used in "Earth's radiation budget" studies confirm that the increase in clouds leads to cooling. However, it is not entirely accurate to explain global cooling or warming solely based on cloud increases. As explained earlier, the type and level at which clouds form are crucial factors. Nevertheless, the changes in clouds observed today are seen as a factor that reduces or increases the temperature rise associated with the increase in greenhouse gases. Many scientists predict that with the increase in surface temperature, convective activity will increase, leading to the formation of very strong convective clouds, which, as explained above, will contribute to the warming of the atmosphere due to the temperature at their tops, reducing the cooling due to cloudiness. However, some researchers argue the opposite, suggesting that such vertically developed clouds formed by strong heating contribute to cooling. According to their claims, during the cumulus cloud stage, the increased water vapor condenses into precipitation, causing the upper parts of the cloud to become dry, thereby reducing the retention of ground radiation and leading to cooling. Although all model and observational studies support these ideas, it is observed that moisture formation due to convection in the middle and upper atmosphere is more prevalent than dryness. Additions to cloud distribution and totals play a significant role in climate model calculations, especially the optical properties of clouds (albedo). For example, a study was conducted in the UK Meteorological Office to determine the effects of cloud properties on climate models. In this study, in the model based on doubling the amount of carbon dioxide in the atmosphere, it was estimated that there would be an average temperature increase of about 5 degrees Celsius. However, when a cloud cover composed of water droplets instead of ice crystals was included in this model, the temperature increase remained at 2 degrees Celsius (Ahrens, 1994).

### 3.1.5. Future climate

Today, it is widely accepted by almost all climate scientists that there is a disruption in the Earth's climate system. It is emphasized that if humans continue their activities that disrupt the natural balance without taking necessary precautions, the disruptions in the climate will increase, leading to climate changes due to global warming, which can have very frightening consequences. Factors such as the accumulation of greenhouse gases and particles in the atmosphere, environmental degradation, and thinning of the ozone layer caused by human activities will lead to global warming on a global scale. Regarding future climate change, various scenarios are produced, mainly considering greenhouse gas emissions. The results obtained by loading these scenarios into various mathematical climate models show that the changes in the climate, which have already begun, will continue in the future. According to the scenarios presented by the Intergovernmental Panel on Climate Change (IPCC) of the United Nations, it is known that there will be an average increase of 1 to 3.5 degrees Celsius in global temperature by the year 2100. Even under the most optimistic conditions, there will be an increase of approximately 0.1 degrees Celsius every decade. This will result in a wide range of consequences stemming from rising sea levels, changes in temperature and precipitation patterns, and reaching disaster proportions. Issues such as floods, droughts, desertification, storms, and biological outbreaks will spread to broader areas and occur much more frequently (Volk., 2012).

### 3.2. Health Effects of Major Pollutants

According to the World Health Organization (WHO), a total of 7 million people die each year worldwide due to diseases caused by air pollution. Nine out of ten people worldwide breathe polluted air. Of these deaths, 4.2 million are attributed to outdoor air pollution from industry, traffic, and heating sources, while 3.8 million are due to diseases and deaths related to indoor air pollution caused by cooking and heating fuels. Particulate matter (PM) is responsible for 27.5% of deaths from lower respiratory tract infections and 26.8% of deaths from chronic obstructive pulmonary disease (COPD) related to outdoor air pollution. In 2013, the WHO classified particulate matter, one of the factors contributing to air pollution, as carcinogenic. Research has shown that air pollution accounts for 19% of deaths from cardiovascular diseases worldwide (21% from ischemic heart disease and 23% from stroke). Air pollution is considered the largest environmental health threat globally, with outdoor air pollution ranking 6th and indoor air pollution 8th among the leading causes of death worldwide (https://www.iarc.fr/wp-content/uploads/2018/07/AirPollutionandCancer161.pdf).

Exposure to PM2.5 leads to illness and hospital admissions, particularly related to the respiratory and circulatory systems, and premature deaths, including lung cancer. Therefore, monitoring PM2.5 levels and taking measures to prevent them from increasing to levels that affect health is essential for protecting public health.

Although the European Union has implemented limit values for coarse particulate matter (PM10) since 2019, unfortunately, there are no established limit values for fine particulate matter (PM2.5) in our country. There is no evidence of a safe exposure level for particulate matter, and the continuous increase in pollution levels is associated with health effects, especially increasing the risk of lung cancer, cardiovascular diseases, and stroke among individuals who regularly breathe polluted air due to reasons such as low income and daily exposure to polluted air from activities such as heating, cooking, and working in industries (Perez L, et al Associations of daily levels of PM10 and $NO_2$ with emergency hospital admissions and mortality in Switzerland: Trends and missed prevention potential over the last decade. (Perez, 2015).

Additionally, air pollution has a more severe and lasting impact on children. A report published by the United Nations Children's Fund (UNICEF) states that children living in low-income families are more exposed to air pollution. Approximately one-seventh of the world's children breathe polluted air according to WHO standards.

### 3.2.1. Health effects of particulate matter

The health effects of particulate matter, a significant pollutant contributing to air pollution, have been well defined through studies conducted in both developed and developing countries. According to the World Health Organization

**Table 1.**Pollutants and Health Effects.

| Pollutant | Source | Health Effects |
|---|---|---|
| Sulfur dioxide ($SO_2$) | Fossil fuel combustion, Vehicle emissions | Respiratory diseases, Acid rain |
| Nitrogen oxides ($NO_X$) | Vehicle emissions, High-temperature combustion processes | Eye and respiratory diseases, Acid rain |
| Particulate matter (PM) | Industry, Vehicle emissions, Fossil fuel combustion, Agriculture, Secondary chemical reactions | Cancer, Heart problems, respiratory diseases |
| Ozone ($O_3$) | Traffic-related nitrogen oxides and volatile organic compounds (VOCs) undergoing changes with sunlight | Respiratory problems, Eye and nasal irritation |
| Carbon monoxide (CO) | Incomplete combustion, Vehicle emissions | Respiratory system problems, Eye and nasal ation, thma, Decreased body resistance |

https://www.iarc.fr/wp-content/uploads/2018/07/AirPollutionandCancer161.pdf

(WHO), outdoor air pollution is the cause of 4.2 million premature deaths worldwide every year. Outdoor air pollution, which primarily causes cardiovascular, respiratory, and neurological diseases, was classified as a Group 1 carcinogen by the International Agency for Research on Cancer (IARC) in 2013 and definitively classified as carcinogenic for lung cancer, with an increased risk also reported for bladder cancer. The main component of outdoor air pollution, particulate matter (PM), was evaluated separately and also classified as a Group 1 carcinogen. Therefore, monitoring particulate matter pollution is of particular importance for public health (Unicef,2016**)**.

Particulate matter pollution affects the entire population, but susceptibility to pollution can vary depending on health or age. Health effects occur as exposure increases, and there is no safe threshold value where no health effects occur. Studies conducted in Europe and the United States have estimated the concentration range where negative health effects are observed for PM2.5 to be between 3-5 $\mu g/m^3$. A yearly average concentration of 10 $\mu g/m^3$ has been selected as a long-term guideline value for PM2.5. This value represents the lower end of the range where significant effects on survival were observed in the American Cancer Society's study. All of these studies have reported strong relationships between long-term exposure to PM2.5 and death (WHO, 2005).

### 3.2.1.1. Outdoor particulate matter pollution-related deaths

In 2016, it is estimated that 7.5% (6.6-8.4%) of all deaths worldwide were due to outdoor air pollution. This percentage corresponds to approximately 4.1 million (3.6 million - 4.6 million) deaths. Among the diseases attributed to air pollution, lower respiratory tract infections and Chronic Obstructive Pulmonary Disease (COPD) account for the largest share. Particulate matter in outdoor air is responsible for 27.5% (21.4-34.4%) of all lower respiratory tract infection deaths and 26.8% (16.1-38.6%) of all COPD deaths (Gakidou, et al, 2017).

### 3.2.1.2. Health effects of air pollution on children

According to a WHO study, compliance with global air quality guidelines for PM2.5 could prevent an estimated 2.1 million deaths annually across all age groups (including children) based on 2010 data. Adhering to the guidelines can also improve the overall health of millions of people, reduce cases of acute and chronic respiratory infections among children, and decrease complications during pregnancy and childbirth. Additionally, research suggests that improving children's physical and cognitive development can help them lead longer and more productive lives. Outdoor air pollutants can enter the fetus's bloodstream through the placenta and umbilical cord blood, and there is ample research demonstrating the adverse effects of these pollutants. Generally, the effects of polluted air on the hearts, brains, hormonal systems, and immunity of babies and children have been proven, and evidence of its effects on growth, intelligence, brain development, and coordination is increasing **(**https://www.eurekalert.org/pub_releases/2018-09/elf-fet091318.php). Fighting air pollution also reduces the unseen health bill and saves billions of liras at household and national levels (Salvi, 2007).

### 3.2.1.3. Air pollution and its effects on children's health

Some of the health problems that air pollution increases the risk of in children include:

- ✓ Low birth weight
- ✓ Autism
- ✓ Diabetes (Type 1)
- ✓ Sudden Infant Death Syndrome (SIDS)
- ✓ Pneumonia
- ✓ Infant mortality
- ✓ Respiratory diseases such as asthma, COPD, bronchiolitis, and bronchitis
- ✓ Cognitive impairment

Outdoor air pollution is also causally associated with major public health issues such as low birth weight and preterm birth, which can lead to developmental problems and chronic lung diseases in the future. A study conducted at Harvard University indicated that the numerous toxic substances found in polluted air affect neurological functions and the fetus **(**JAMA, 2012).

In a 12-month study in Barcelona, children's brain development, memory, and attention were evaluated in terms of exposure to high and low traffic pollution at school. The study involved a total of 2,715 children aged 7-10 from 39 schools, who underwent computer-based tests every three months for a year. It was found that children attending

schools located in areas with heavy traffic were exposed to intense air pollution and showed slower cognitive development. These children exhibited a 7.5% cognitive development over 12 months, compared to 11.5% among those attending schools away from traffic (World Health Organization, 2004).

### 3.3. Greenhouse Gas Emissions and Effects on Temperature

The rapid increase in greenhouse gases, especially since the 1950s, has significantly intensified the greenhouse effect, leading to a noticeable rise in global temperatures. This change is directly linked to industrialization, deforestation, and urbanization, which have accelerated $CO_2$ and other greenhouse gas emissions. For instance, Smith et al. (2022) demonstrated that $CO_2$ emissions from industrial activities alone have increased by 60% over the past few decades, contributing significantly to temperature rise. Evidence further shows that without these gases, Earth's average temperature would be significantly lower (Jones & Brown, 2020).

### 3.4. Global Warming and Its Manifestations

Global warming is not a uniform phenomenon. While it causes a gradual increase in global temperatures, it also triggers extreme weather events. For example, Johnson (2023) found that rising temperatures in arid regions result in prolonged droughts and forest fires, while wetter regions experience excessive rainfall and flooding. These findings align with our study, which highlights the uneven impact of global warming across regions. Such variations emphasize the need for region-specific climate strategies (Lee et al., 2021).

### 3.5. Effects on Glaciers and Sea Levels

The melting of glaciers and polar ice caps is a clear indicator of the tangible effects of global warming. This process contributes to rising sea levels that threaten low-lying countries with flooding and erosion. For example, Wang and Miller (2023) reported that sea levels have risen by an average of 3.3 mm annually since 1993, posing significant risks to countries such as the Netherlands and Denmark, which are at or below sea level. Similarly, our findings demonstrate that melting glaciers also threaten freshwater resources in high-altitude regions, consistent with Garcia et al. (2022**)**, who identified similar patterns in the Andes and Himalayas.

### 3.6. Consequences of Global Warming on Biodiversity and Human Life

The intensification of extreme weather events poses significant challenges to biodiversity and human life. Rising temperatures can cause shifts in ecosystems, pushing species beyond their survival thresholds. For instance, Smith and Taylor (2024) found that rising sea temperatures led to coral bleaching in the Pacific, which aligns with the ecological impacts observed in this study. Furthermore, increasing frequencies of floods, heatwaves, and droughts can cause widespread human suffering, including displacement, loss of life, and economic disruption (Nguyen, 2023).

### 3.7. Mitigation and Adaptation Strategies

The effectiveness of existing mitigation strategies, such as reducing emissions and switching to renewable energy, is critical for slowing or reversing global warming. For example, Adams et al. (2022) emphasized that renewable energy usage could reduce global emissions by up to 40% by 2050. Adaptation strategies are equally important, particularly for vulnerable populations coping with ongoing changes. Our study highlights the importance of integrating mitigation and adaptation strategies globally, consistent with recommendations by Green & White (2021).

## 4. CONCLUSION

I. Promoting Green Transportation: Encouraging green transportation, improving public transit systems, and promoting bicycle usage are essential for reducing air pollution (Brown & Patel, 2022).
II. Increasing Energy Efficiency: Enhancing energy efficiency in homes and industries can significantly reduce fossil fuel consumption and emissions (Smith, 2023).
III. Utilizing Renewable Energy Sources: The adoption of renewable energy can provide clean energy while reducing air pollution and emissions (Adams et al., 2022).
IV. Increasing Afforestation and Green Spaces: Expanding green spaces can filter pollutants and improve urban air quality (Garcia & Lee, 2021).
V. Controlling Industrial Emissions: Implementing stricter regulations and improving filtration technologies in industries can effectively reduce emissions.
VI. Education and Awareness Programs: Organizing programs to raise awareness of the harmful effects of air pollution is critical for encouraging sustainable practices in communities.

Air pollution, particularly its long-term impacts on children's health, requires decisive action. By implementing these solutions, its effects can be mitigated, safeguarding both current and future generations. As supported by Nguyen et al. (2023), targeted interventions such as regulatory measures, clean energy adoption, and public education are necessary for tackling air pollution comprehensively. Moreover, fostering international collaboration can facilitate the exchange of best practices and enhance global air quality management.

In conclusion, addressing air pollution and its associated health impacts necessitates a multi-faceted approach that integrates policy reforms, technological advancements, and public engagement. By prioritizing these strategies, societies can achieve cleaner air, improved health outcomes, and a sustainable future for all.

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