

Impact of Heat Exposure on Human Health

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ABSTRACT

This systematic review delves into the significant impacts of heat exposure on human health, focusing on vulnerable groups, such as individuals with asthma, pregnant mothers and infants, and outdoor workers. By examining current literature, the study sheds light on the growing challenge of heat events triggered by climate change, revealing the varied health effects of heat exposure and the heightened vulnerability of specific groups. The findings highlight a troubling trend of more frequent and severe heat events, posing increased health risks for people from diverse backgrounds. Pregnant women, infants, outdoor workers, and people with asthma are particularly at risk, facing higher rates of heat-related illnesses and negative health outcomes. For mothers and infants, higher temperatures are related to smaller fetal growth measures, higher odds of small for gestational age, and severe maternal morbidity. Additionally, the review identifies gaps in research, emphasizing the urgent need for comprehensive strategies to mitigate climate change's impact on health. Proposed mitigation measures include targeted interventions for vulnerable populations, improved workplace safety measures, and increased public awareness about heat-related illnesses. This study underscores the pressing need to address climate change to protect public health and manage the growing risks associated with extreme heat events. It contributes valuable insights into the complex relationship between climate change and human health, informing efforts to build resilience and adaptation in the face of a warming world.

KEYWORDS

Climate change, extreme heat, environmental health, heat-related illnesses, systematic review

INTRODUCTION

The United Nations Intergovernmental Panel on Climate Change (IPCC) reported in 2021 that human activity had increased Earth's temperature by 1.1°C since 1900 and warned that it will unalterably reach 1.5°C above 1900 levels in less than 20 years. This evolving climate crisis is demonstrated by the increased occurrence of extreme weather events such as heat waves and wildfires (Patel et al. 2022). Escalating temperatures and increasing frequency of heat events like heat waves are posing profound challenges to both the environment and human health. Different regions in the United States are suffering from heat exposure and heat-related illness. Reports state that at least a dozen more deaths happen on extreme heat days in Los Angeles County compared to past years, and the data did show heat-related deaths in California more than doubled from 2019 to 2020: 63 to 133 heat-related deaths, respectively (Lopez 2023). However, extreme temperature and heat exposure caused mortality and emergency department visits did not just occur in California. News and government reports on cities like Phoenix, Houston, and Seattle all show an increasing trend of mean daily number of heat-related illness emergency department visits, including heat-related deaths compared to past years (DOH 2021). As a result, it is essential to learn how heat exposure affects human health, since such knowledge improves health care preparedness.

The aim of this project is to investigate how heat exposure affects human health through a systematic review, with a targeted focus on vulnerable demographics—people with asthma, pregnant mothers, infants, and outdoor workers—whose well-being is disproportionately impacted by the warming climate. The first section starts with the challenge of the growing problem of climate change and heat events. The second section delves into the intricate health consequences like heat related illnesses for individuals. The third section spotlights vulnerable groups with higher risk of having severe health problems. Then, with the conclusion from the first three sections, the fourth section provides possible solutions for individuals, communities, and even the governments. The last section discusses possible areas for further research and, again, emphasizes the urgent response to global warming.

Understanding the Growing Problem

In recent decades, the United States has observed an alarming and persistent trend marked by the increasing frequency and severity of heat events and is projected to continue (US EPA 2021). These events are characterized by heightened temperatures and prolonged heat waves. They emerge as existential threats to human health. The first section of this paper will illuminate the expanding scope of the problem and underscoring the serious health effects on individuals.

Unraveling Health Consequences

With the growing prevalence of heat events, the frequency of people having temperature-related health issues, such as illness and death, is increasing (NIH 2022). The corresponding section later in this paper introduces common heat related diseases and symptoms, as well as news reports on heat related health outcomes. By delving into existing literature and empirical evidence, we aim to provide a nuanced understanding of the diverse health effects arising from heightened temperatures.

Spotlighting Vulnerable Demographics

Among the challenges posed by climate-induced heat exposure, certain demographic groups are particularly vulnerable. Pregnant mothers and infants, individuals with asthma, and outdoor workers face higher health risks that demand targeted interventions. This section indicates detailed findings of health impact among published literature for each targeted group, shedding light on the need for health considerations and interventions.

Proposing Solutions and Urgent Appeal

The last two sections of this paper provide suggestions and recommendations for individuals, communities, and the public to better avoid serious health consequences under heat exposure. Further research and the appeal of urgent acts on global warming/ climate change will be discussed as well.

BACKGROUND

The Growing Problem

In recent decades, the United States has observed an alarming and persistent trend marked by the increasing frequency and severity of heat events, a trend that has continued into the present day. According to the Environmental Protection Agency (EPA), heat waves are now more prevalent in major U.S. cities, with their frequency steadily rising from an average of two heat waves annually during the 1960s to six per year in the 2010s and 2020s. Moreover, these heat waves have intensified over time. In the 1960s, the average heat wave in 50 major cities exceeded the 85th percentile threshold by 2.0°F, while in the 2020s, the average heat wave surpassed this threshold by 2.3°F (US EPA 2021).

From 2021 to 2023, the United States has grappled with an unrelenting surge in heat events, characterized by soaring temperatures and extended heat waves that profoundly impact various aspects of society. The escalation in heat events can be attributed to the influence of climate change, which has led to notable shifts in weather patterns. Notably, the average heat wave season across 50 major cities has stretched 49 days longer than it was in the 1960s, exacerbating the challenges posed by these heat waves (USGCPR 2021). As a result, these heat waves have become not only more frequent but also significantly lengthier in duration, amplifying their impact on public health, agriculture, and energy demand (US EPA 2021).

According to ABC News on December 27, 2023, “throughout 2023, records for the warmest temperatures around the world were broken one by one, but record-eclipsing temperatures will no longer be an anomaly if greenhouse gas emissions that fuel global warming continue at the current pace, according to climate scientists.” Scientists at NASA have found the global average temperature in 2023 was about 1.37 degrees Celsius higher than preindustrial levels (Zhong and Collins 2024). Global temperatures started blowing past records midyear and didn’t. First, June was the planet’s warmest June on record. Then, July was the warmest July. And so on, all the way through December. Temperatures during 2023 likely exceed those of any period in at least the last 100,000 years (Copernicus 2024).

El Paso, Texas, saw a record stretch of 44 consecutive days at or over 100 degrees in June and July, smashing the previous record of 23 consecutive days set in 1994, records show (Jacobo

2023). Phoenix, Arizona, saw a record-shattering stretch of 31 days at 110 degrees or greater, surpassing the previous record of 18 consecutive days (Jacobco 2023). All these signs have shown a serious problem of climate change and how it affects the daily temperatures during 2023. As a result, it is essential for people to be aware of the consequences that extreme temperatures/heat events bring, since there is a one-in-three chance that 2024 will be warmer than 2023, and a 99% chance that 2024 will rank among the top five warmest years (NOAA 2024).

Health Consequences

People getting health issues because of heat exposure/extreme temperature seems to be more frequent and common in the US. According to the National Weather Service in Phoenix, July wrapped up with an average temperature of 102.7 degrees Fahrenheit, beating the Phoenix area's previous record of 99.1 degrees, set back in August 2020, and 14 more heat-associated deaths have been reported, according to the weekly Maricopa County Heat report released Wednesday morning (Cervantes 2023). People experiencing either sheltered or unsheltered homelessness are particularly vulnerable to heat-related illnesses, including heat exhaustion, heat stroke, and dehydration (du Bray et al. 2023). Report on Las Vegas concluded that emergency department visits related to the heat across Nevada in July more than doubled, compared to the same period last year, according to the Centers for Disease Control and Prevention (Solis et al. 2023). As more cities are suffering from extreme temperatures, it is essential to understand how heat exposure affects the human body and what symptoms will appear.

Heat-related illness can be dangerous for people of a certain age, and it is important to have medical treatment once symptoms are shown. However, people might not be so familiar with heat-related illnesses and sometimes ignore the urgency of recognizing symptoms. There are a total of three heat related illnesses, heat exhaustion is one of three heat-related illnesses, with heat cramps being the mildest and heatstroke being the most serious. Heat stroke occurs when the body can no longer control its temperature: the body's temperature rises rapidly, the sweating mechanism fails, and the body is unable to cool down (NIOSH 2023). When heat stroke occurs, the body temperature can rise to 106°F or higher within ten to fifteen minutes, and it is fatal if treatment is delayed. Symptoms of heat stroke include loss of consciousness, very high body temperature, seizures, and altered mental status. Heat exhaustion is the body's response to an excessive loss of

water and salt, usually through excessive sweating (NIOSH 2023). It is most likely to affect the elderly and people with high blood pressure. Symptoms of heat exhaustion may start suddenly or progress over time, especially with prolonged periods of exercise. Possible heat exhaustion symptoms include heavy sweating, faintness, dizziness, fatigue, weak and rapid pulse, low blood pressure upon standing, muscle cramps, nausea, and headache. Heat cramp, as the mildest, usually affects workers who sweat a lot during strenuous activity (NIOSH 2023). Sweating depletes the body's salt and moisture level. When the salt level in muscle is low, painful cramps will occur.

According to Boston University's report, in addition to extreme cases, hot days are also associated with higher risk of several other conditions that are not typically thought to be “heat-related,” such as kidney problems, skin infections, and preterm birth among pregnant women (Thornton 2023). After all, heat stroke can cause permanent disability or death if the person does not receive emergency treatment. Infants, children younger than 4 and adults older than 65 are all at higher risk of heat exhaustion.

METHODS & RESULTS

Vulnerable Demographics

My study design for this systematic review was supported by multiple published literature from various websites. I started the systematic review by grouping my target demographics into three categories: people with asthma, pregnant mothers and infants, and outdoor workers. I searched papers for each group in order. Some keywords I used to get a better match include heat, extreme temperatures, and heat related illnesses, etc. With these accumulated papers, I reviewed them and carefully focused on each paper's methods and the corresponding result. I utilized tables for each vulnerable demographic to show my findings. Each table includes articles' names, authors and dates, methods used, and results.

How does heat exposure affect people with asthma?

According to the National Institute of Health, asthma is a chronic condition that affects the airways in lungs. The airways can become inflamed and narrowed for people with asthma. This makes it harder for air to flow out of airways when people breathe out (NHLBI 2024). Asthma can affect people for all ages and it usually starts during childhood. Allergies, environmental factors, genetics, and respiratory infections can all present higher risks for people to get asthma (CDC 2023). People can develop asthma after exposure to things that irritate the airways. These substances include allergens, toxins, fumes, and second-or third-hand smoke. Besides, air pollution, exercise, and certain occupational exposures are all common asthma attack triggers. Symptoms of asthma include difficulty in breathing, sometimes together with dizziness, fatigue, and fainting. However, people can have different symptoms and signs at different times with chronic asthma. Also, difficulty in breathing does not mean an asthma attack happened, cardiovascular and other diseases can cause such symptoms as well.

Warmer temperatures and shifting weather patterns can worsen air quality, which can lead to asthma attacks and other respiratory health effects (APHA 2024). Warmer temperatures from climate change will increase the frequency of days with unhealthy levels of ground-level ozone, a harmful air pollutant, and a component in smog. Ground-level ozone can damage lung tissue,

reduce lung function, and inflame airways (IQAir 2023). This makes people with asthma more vulnerable. The table below summarizes the literature that provides evidence of heat exposure causing harmful effects for people with asthma.

Table 1. Summary tables based on searched literature for people with asthma. Summary of articles with results of heat exposure on people with asthma.

Article Name	Authors and Publish Date	Methods	Result
<i>Emergency department asthma diagnosis risk associated with the 2012 heat wave and drought in Douglas County NE, USA</i>	Figgs 2019	Observational, retrospective, case-control study Heatwave exposure measurement: <ul style="list-style-type: none"> ED asthma risk by admission year model ED asthma risk by temperature model: DMAT was $>$ DMAT_m (median daily mean ambient temperature) classified as exposed, DMAT was \leq the DMAT_m classified as unexposed. 	ED admission and DMAT were negatively correlated during the 2011 risk period, but positively correlated during the 2012 risk period. Persons diagnosed with asthma were disproportionately younger than 19 years old, were male, were African American, and were admitted during the 2012 risk period compared to the 2011 risk period.
<i>Warm Season and Emergency Department Visits to U.S. Children's Hospitals</i>	Bernstein et al. n.d. 2022	First-stage analysis: Distributed-lag nonlinear models with a Quasi-Poisson distribution to estimate the association between day-to-day variation in maximum temperature and the relative risk of ED visits separately for each of the 47 hospitals participating in the Pediatric Health Information System at the time of analysis. Second-stage analysis: Random-effects meta-analytic model to estimate the overall cumulative association between heat and ED visits across the 47 hospitals.	Days of extreme heat were most strongly associated with higher rates of ED visits for heat-related illness, bacterial enteritis.
<i>The association between ambient temperature</i>	Xu et al. 2018	Systematic Review: PubMed, ProQuest, ScienceDirect, and	Among all 12 studies which examined the

<i>and childhood asthma: a systematic review</i>	Scopus, were used to retrieve papers examining the short-term effects of absolute temperature and intra- or inter-day temperature variation on childhood asthma which were published between 1 January 2000 and 31 December 2016. Children are defined as age under 18.	effects of ‘heat’ or ‘both heat and cold’ on childhood asthma, eight studies have found a significant effect of heat on childhood asthma. As the possible effect of ambient high/low temperature on childhood asthma may not occur immediately after exposure, and both high and low temperatures may affect childhood asthma.
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<i>The Role of Extreme Weather and Climate-Related Events on Asthma Outcomes</i>	Rorie and Poole 2021	Literature review	The peak asthma admission rates coincided with the most consecutive days of intense heat and the apex was during the hottest time of day. Subjects who were children or African American were threefold more likely to be seen for an asthma exacerbation.
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How does heat exposure affect pregnant mothers and infants?

According to the CDC, pregnant women are more likely to get heat exhaustion, heat stroke, or other heat-related illness compared to nonpregnant women. This is due to their bodies having to work harder to cool down both their body and the developing baby. Pregnant women are also more likely to become dehydrated, which means they are not able to cool themselves by sweating. More serious consequences occur as well. Mothers exposed to high temperatures suffer with increased rates of miscarriage, congenital abnormalities, stillbirth, and low birth weight babies (Chersich et al. 2020). Besides, there is growing evidence that pregnant women are less able to appropriately thermoregulate; however, when exposed to extreme heat, there are several processes

that may occur which could harm the mother or fetus including a reduction in placental blood, dehydration, and an inflammatory response that may trigger preterm birth (Samuels et al. 2022).

Extreme heat exposure is affecting both pregnant women and their infants. Exposure to hot weather at the end of pregnancy is associated with shorter gestational age. For example, a one-day exposure to temperatures above 87 degrees Fahrenheit was associated with a decrease in the average length of pregnancy by five days; fetuses exposed to heat waves while in utero were more likely to suffer from fetal distress and breathing problems at birth (NPWF 2021). The table summarizes the literature that provides evidence of heat exposure causing harmful effects on pregnant mothers and infants.

Table 2. Summary tables based on searched literature for pregnant mother and infants. Summary of articles with results of heat exposure on pregnant mothers and infants.

Article Name	Authors and Publish Date	Methods	Result
<i>Ambient temperature during pregnancy and fetal growth in Eastern Massachusetts, USA</i>	Leung et al. 2023	Ultrasound measurements of biparietal diameter (BPD), head circumference (HC), femur length and abdominal circumference (AC), in addition to birth weight (BW) from 9446 births at Beth Israel Deaconess Medical Center from 2011 to 2016.	Higher ambient temperature was associated with smaller fetal growth measures. Higher temperatures were associated with impaired fetal growth.
<i>Ambient Temperature and Markers of Fetal Growth: A Retrospective Observational Study of 29 Million U.S. Singleton Births</i>	Sun et al. n.d.	Two-stage approach to estimate the association between mean temperature decile and either relative odds of small for gestational age (SGA) or change in birth weight z-score: <ul style="list-style-type: none"> ● logistic regression to estimate the odds ratio. ● random-effects meta-analytic models to combine the county-specific estimates obtained from the first stage. 	Warmer-than-average temperatures were associated with higher odds of SGA. Temperatures above the 90th percentile were more strongly associated with lower birth weight in the Northeast and Northwest regions and in the marine and cold/very cold climate zones.
<i>Maternal ambient heat</i>	Lin et al. 2018	Extreme heat events (EHEs) were	3–11 days of EHE90

<i>exposure during early pregnancy in summer and spring and congenital heart defects – A large US population-based, case-control study</i>	defined by using the 95th (EHE95) or 90th (EHE90) percentile of daily maximum temperature and its frequency and duration during postconceptional weeks 3–8.	during summer and spring was significantly associated with ventricular septal defects (VSDs) study-wide. EHE95 in spring was significantly associated with conotruncal defects and VSDs in the South.
	Calculate exposure odd rates (OR) through multivariate logistic regression analyses, while controlling for potential confounding factors.	

<i>Analysis of Heat Exposure During Pregnancy and Severe Maternal Morbidity</i>	Jiao et al. 2023	Identified severe maternal morbidity cases during delivery hospitalization based on the US Centers for Disease Control and Prevention SMM index.	SMM ₂₀ and SMM _{cardio} were mainly associated with heat exposure during the entire pregnancy and the third trimester. The magnitude of associations was higher for more severe heat exposure.
		Discrete-time logistic regression to examine associations between long- and short-term heat exposure and SMM.	For short-term heatwave exposure and risk of SMM, all associations were significant under different heat wave definitions, and the magnitude of them increased from the least severe to the most severe heat wave exposure.

How does heat exposure affect outdoor workers?

Millions of U.S. workers are exposed to heat in their workplaces. Although illness from exposure to heat is preventable, every year, thousands become sick from occupational heat exposure, and some cases are fatal (OSHA 2020). Workers who are exposed to extreme heat while engaged in strenuous physical activities outdoors have an increased risk for heat stress. Heat can also increase the risk of injuries because it may lead to sweaty palms, fogged-up safety glasses, and dizziness, and may also reduce brain function, leading to impaired reasoning ability, and thereby create additional hazards. The internal body temperature will keep rising if heat dissipation

does not happen in time, and as a result, outdoor workers will experience symptoms like thirst, irritability, a rash, cramping, heat exhaustion, or heat stroke, and even death. The table summarizes the literature that provides evidence of heat exposure causing harmful effects on outdoor workers.

Table 3. Summary tables based on searched literature for outdoor workers. Summary of articles with results of heat exposure on outdoor workers.

Article Name	Authors and Publish Date	Methods	Result
<i>Evaluation of wearable sensors for physiologic monitoring of individually experienced temperatures in outdoor workers in southeastern U.S.</i>	Runkle et al. 2019	Based on average daily maximum temperatures and heat index measures at each study site, exposure groups were assigned as follows: ASU was designated as the moderate temperature exposure group, MSU was the high temperature, high humidity exposure group, and NCSU was the high temperature exposure group. Each participant was equipped with a ThermoChroni Button to measure direct exposure to ambient temperature over 5-minute intervals throughout the workday.	For every 1 °F/0.552 °C increase in temperature, the risk of a heat strain event increased 3% for all exposure groups combined and was more pronounced for workers in the “high temperature” environment. The effect of temperature on heat strain was nonlinear and characterized by much higher relative risks (RRs) at higher temperatures for the “high temperature” group over a wide range of temperatures (~29.4 °C/85 °F to 35 °C/95 °F) compared to the “moderate temperature” exposure group. The relative risk for heat strain was statistically significant from 85 °F to 95 °F.
<i>Mortality and Morbidity during Extreme Heat Events and Prevalence of Outdoor Work: An Analysis of Community-Level Data from Los Angeles County,</i>	Riley et al. 2018	Examined rates of deaths, ED visits, and hospitalizations at the zip code level in Los Angeles County and considered them in relation to the proportion of residents living in those zip codes who are employed in outdoor industries.	Rates of heat-related ED visits during summer heat events were significantly higher in communities with a greater proportion of residents working in either construction or agriculture,

California	Poisson regression models were used to model the number of events in each zip code for each outcome.	forestry, fishing and hunting, and mining after adjusting for age, race, and poverty.
<i>A Case-Crossover Study of Heat Exposure and Injury Risk in Outdoor Agricultural Workers</i>	Spector et al. 2016 A case-crossover study using time-stratified referent selection among 12,213 outdoor agricultural workers with new Washington State Fund workers' compensation traumatic injury between 2000 and 2012. Conditional logistic regression to estimate odds ratios of injury for <i>a priori</i> daily maximum Humidex categories.	The traumatic injury odds ratio was 1.14 (95% confidence interval 1.06, 1.22), 1.15 (95% confidence interval 1.06, 1.25), and 1.10 (95% confidence interval 1.01, 1.20) for daily maximum Humidex of 25–29, 30–33, and ≥ 34 , respectively, compared to < 25 , adjusted for self-reported duration of employment. Stronger associations were observed during cherry harvest duties in the June and July period, compared to all duties over the entire study period. Agricultural workers laboring in warm conditions are at risk for heat-related traumatic injuries.

Strengths

This systematic review offers valuable insights into the significant impacts of heat exposure on human health, particularly focusing on vulnerable groups such as individuals with asthma, pregnant mothers and infants, and outdoor workers. The strength of this thesis lies in its comprehensive approach to gathering and analyzing existing literature on the topic. Systematic review ensures a thorough examination of available research. It provides a comprehensive overview of the current understanding of the effects of heat exposure for different vulnerable groups in various locations in the US, which allow people to have a better perspective on heat-related health issues.

Limitations

Literature collected is the most updated that is available through online search tools using relevant keywords. However, most of these papers used data that is far from recent ones. Most of the papers found in the search used data from 2016. One possible reason is that 2016 is the hottest year on record before 2023, so data from this year is capable of showing some serious problems of extreme heat exposure affecting humans' health.

Besides, it is impossible to obtain heat exposure and health outcomes measured for individuals. This is true for several reasons. First, investigators doing secondary research cannot obtain medical information for individuals, for confidentiality reasons. In addition, we cannot obtain addresses or direct measures of heat exposure. Even if information of location is available, the nearest temperature that triggers patients to get health-related illnesses is still unknown, and several factors such as pollutant and humidity might influence the result as well. Second, it is unethical to carry out the experiments that would be needed with human subjects. An ideal way to gain individual data is to have small instruments in people's homes to measure humidity, pollution level, and eat level, etc.

As a result, it would be difficult to demonstrate a direct causal connection between heat exposure and health outcomes, but it is true that the annual temperature is rising each year and there tends to be more ED visits. After all, more studies related to heat exposure and human health problem should be considered.

DISCUSSION

In recent years, the world has witnessed an alarming rise in temperatures, leading to unprecedented heat waves that have left communities grappling with the harsh realities of extreme heat exposure. Serious impact from extreme heat exposure has been discussed, especially for certain vulnerable groups. As we confront the intensifying effects of climate change, addressing the pressing issue of extreme heat becomes imperative for both the well-being of our planet and humans ourselves.

Proposing Solutions

As extreme heat exposure is more frequent in recent years, it is essential for both the society and individuals to be prepared. Unfortunately, currently, there are no federal heat protection standards in the US. The Occupational Safety and Health Administration (OSHA) has a rule that states employers have a duty to ensure a healthy and safe work environment, but heat is not specifically mentioned. This means the basic standards for outdoor workers' health might not be met under extreme heat exposure. In some states like California, science-informed heat protection standards do exist; however, implementation varies from employer to employer, field to field. It is possible that employers do not offer information on signs and symptoms of heat-related illnesses and laws protecting workers from heat. Some employers might not provide enough water or shade to outdoor workers under extreme heat since it would become extra money spending.

Current rules and laws cannot effectively protect outdoor workers under heat exposure. As a result, people need better laws to protect themselves, and there are a lot more things that the government can do. For example, as the global temperature continues rising, hotter temperatures in all months will become more common. In this case, federal laws or state laws should provide an accurate temperature when people should not engage in outdoor activities and provide detailed information on the consequences of extreme heat exposure. Workplaces should also be served with extra water sources and shaded areas for workers to rest. In addition, for some states like Texas and Arizona that usually have a temperature above 90 Fahrenheit in summer, it is essential for the government to ensure communities, especially those for minorities, have access to air conditioning, since high indoor temperature can also lead to health issues.

People are paying more attention to extreme heat in recent years. News reports show many serious cases due to people's lack of knowledge of heat-related illnesses under heat exposure. Education for all individuals would be useful and important. For instance, people should be aware of some obvious symptoms of heat-related illnesses and be familiar with methods to avoid worse health problems. People with asthma should understand that the change of temperature, especially when it is too hot both indoors and outdoors, will cause bad air quality, which might lead to asthma attacks. It is possible to avoid asthma attacks due to air quality if people receive the warning signs. For example, weather apps have already shown the air quality index, but it would be more beneficial to mention the risk of asthma attack when the AQI (air quality index) increases. For pregnant mothers, doctors and nurses should mention how extreme high temperatures are leading to severe maternal morbidity and mortality, and how bad it will be for the infants if mothers are exposed to heat. After all, there should be a guarantee that all vulnerable groups of people can have professional support if they need them.

Urgent Appeal on Climate Change

In the face of escalating environmental threats and impending human health issues, there is an urgent need for concerted global action to address the critical issue of climate change. Climate change refers to long-term shifts in temperatures and weather patterns. Such shifts can be natural, due to changes in the sun's activity or large volcanic eruptions. But since the 1800s, human activities have been the main driver of climate change, primarily due to the burning of fossil fuels. Greenhouse gas emissions, atmospheric greenhouse gas concentrations, atmospheric black carbon concentrations, and acidification of coastal waters all lead to an increase in average annual global temperature. The change in climate includes various aspects: average annual air temperature and extreme heat events; it affects both the physical (glacier change, snowmelt runoff, sea level rise, etc.) and biological systems (humans, vegetation, wildlife).

Temperature change, especially warmer air temperatures, can alter precipitation and runoff patterns, which affect the availability of freshwater supplies. It can also increase the risk of severe weather events such as heat waves and intense storms, and as a result, bring negative consequences for ecosystems and humans' well-being. As discussed in this thesis, heat exposure can have serious health consequences, especially when extreme heat occurs. As defined, extremely hot days and

nights are when temperatures are at or above the highest 2 percent of maximum and minimum daily temperatures, respectively. However, such days are becoming more frequent at a quite fast rate in the past 30 years. In addition, heat waves are increasing especially at night, and nighttime heat waves, which were infrequent until the mid 1970s, have increased markedly over the past 40 years.

Climate change is a serious issue that our society is facing, and we humans must take actions to mitigate the impact that climate change brings. According to the White House's Fifth National Climate Assessment Detailed Impacts of Climate Change on Regions Across the United States, gradual changes in average climate conditions, such as shifts in temperature and precipitation, and extreme events like floods and wildfire can lead to geopolitical instability and mass migration. These compounding impacts affect people's well-being, the economy, and national security. It is time to act on climate change for a better future.

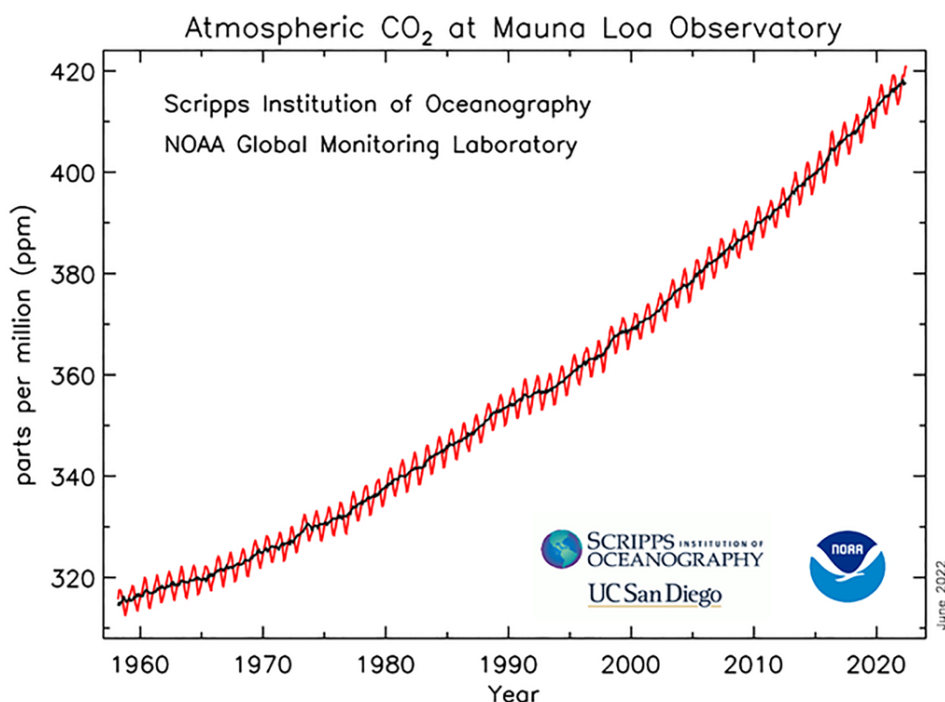


Figure 1. Atmospheric Carbon Dioxide at Mauna Loa Observatory. This graph shows the monthly mean carbon dioxide measured at Mauna Loa Observatory, Hawaii, the longest record of direct measurements of CO₂ in the atmosphere. Monitoring was initiated by C. David Keeling of the Scripps Institution of Oceanography in March of 1958 at a NOAA weather station. (NOAA Global Monitoring Laboratory, Scripps Institute of Oceanography at the University of California San Diego.)

One thing to mention is that greenhouse gas is not an entirely bad thing. These atmospheric gasses can trap the sun's heat and warm the surface of the earth. The presence of a certain amount of these gasses makes the earth habitable since it would otherwise be covered in ice. However, human activity has dramatically increased the concentration of certain greenhouse gasses, like carbon dioxide, by releasing additional carbon that was previously stored in the ground as coal or unrefined oil. Global warming is the result of humans' fossil fuels' usage. Therefore, nowadays, the most important thing is to reduce greenhouse gas emissions. First and foremost, transitioning to renewable energy sources such as solar, wind, and hydropower can significantly diminish reliance on fossil fuels, the primary source of carbon dioxide emissions. For example, regions like California which have enough sunshine can support the development of solar energy techniques. Buildings and transportations are all applicable for a transition to clean energy. Additionally, promoting afforestation and reforestation efforts can act as natural carbon sinks, absorbing carbon dioxide from the atmosphere. Finally, it is essential to implement policies like carbon pricing that incentivize emission reductions. In summary, addressing climate change demands immediate and collective action. By prioritizing the reduction of greenhouse gas emissions, humans can mitigate the adverse effects of global warming and secure a sustainable future for our planet.

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