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Climate Resilience and Adaptation: Impact on Human Well-being

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ABSTRACT
Climate change poses significant risks to public health, impacting various aspects of human well-being. This paper explores the multifaceted health impacts of climate change, including heat-related illnesses, respiratory and cardiovascular diseases, and the emergence of vector-borne diseases. With increasing global temperatures, heatwaves have become more frequent, leading to heightened risks of heatstroke and exacerbated cardiovascular conditions, particularly among vulnerable populations such as the elderly and children. Additionally, deteriorating air quality due to climate change contributes to respiratory issues, including asthma and chronic obstructive pulmonary disease. The shifting habitats of disease vectors, such as mosquitoes and ticks, facilitate the spread of diseases like malaria and dengue fever, presenting new public health challenges. Moreover, climate change threatens water and food security, increasing the risk of waterborne diseases and malnutrition. Mental health is also adversely affected, with climate anxiety and psychological stress linked to extreme weather events. This paper emphasizes the need for equitable public health policies and adaptation strategies to mitigate these impacts, particularly for vulnerable communities. As climate change continues to evolve, comprehensive public health approaches are essential to safeguard health and well-being.
Keywords: Climate change, public health, cardiovascular diseases

INTRODUCTION

Climate change is one of the most pressing global challenges of the 21st century, fundamentally altering the environment and posing significant risks to human health. Defined as long-term alterations in temperature, precipitation, and other atmospheric conditions, climate change is primarily driven by human activities, notably the burning of fossil fuels, deforestation, and industrial processes, which increase concentrations of greenhouse gases in the atmosphere (Intergovernmental Panel on Climate Change [IPCC], 2021). The consequences of these changes are far-reaching, affecting ecosystems, economies, and communities worldwide.

The health impacts of climate change are diverse and complex, manifesting in both direct and indirect ways. Direct effects include heat-related illnesses from increased temperatures and extreme weather events such as hurricanes and floods, which can lead to injuries and fatalities (Haines & Ebi, 2019). Indirectly, climate change influences the spread of infectious diseases, exacerbates respiratory and cardiovascular conditions due to degraded air quality, and threatens food and water security, leading to malnutrition and waterborne illnesses (Patz & Balbus, 2008; Ramin & Sadler, 2009).

Moreover, the mental health implications of climate change are garnering increasing attention, as extreme weather events contribute to anxiety, depression, and post-traumatic stress disorder (Khanna & Dutta, 2021). Vulnerable populations, including low-income communities and those with pre-existing health conditions, bear a disproportionate burden of these health risks, underscoring the need for equitable public health responses (McMichael & Lindgren, 2011).

Aim and objectives of the study

This paper aims to explore the multifaceted health impacts of climate change;
Specifically the paper:

i. emphasize the urgent need for comprehensive adaptation strategies and,
ii. public health policies to mitigate these challenges.

Climate Change and Public Health

Climate change significantly impacts public health through various direct and indirect pathways. As global temperatures rise, extreme weather events, such as heat waves and hurricanes, are becoming more frequent and intense. These changes lead to an increase in heat-related illnesses, including heat exhaustion and heatstroke, particularly affecting vulnerable populations such as the elderly, children, and those with pre-existing health conditions (Haines & Ebi, 2019). The World Health Organization (WHO) has identified heatwaves as a major public health threat, predicting that without adequate adaptation measures; the number of deaths related to extreme heat will rise dramatically in the coming decades. Air

quality is another critical aspect of public health affected by climate change. Increasing temperatures can exacerbate air pollution, leading to higher levels of ground-level ozone and particulate matter. These pollutants are known to cause respiratory diseases, including asthma and chronic obstructive pulmonary disease (COPD), affecting millions globally (Bell & Davis, 2020). Studies have shown that air quality deterioration due to climate change correlates with increased hospital admissions and premature deaths, particularly among vulnerable groups (McMichael & Lindgren, 2011).

Moreover, climate change influences the distribution and incidence of vector-borne diseases, such as malaria and dengue fever. Shifts in temperature and precipitation patterns create favourable conditions for disease vectors like mosquitoes and ticks, leading to the emergence and re-emergence of these diseases in previously unaffected regions (Patz & Balbus, 2008). The World Health Organization has warned that climate change could result in an additional 2 billion people being at risk of vector-borne diseases by 2100.

The indirect effects of climate change also extend to food and water security. Increasingly erratic weather patterns impact agricultural productivity, leading to food shortages and malnutrition, which are particularly detrimental to children and vulnerable populations (Ramin & Sadler, 2009). Additionally, extreme weather events can compromise water quality and availability, increasing the risk of waterborne diseases such as cholera (Patz & Balbus, 2008).

In summary, climate change poses significant and multifaceted threats to public health, necessitating immediate and coordinated responses from policymakers, public health officials, and communities to mitigate its impacts effectively.

Specific Illnesses and Diseases

Heat-Related Illnesses

Increased Frequency and Intensity of Heatwaves

Climate change has led to a marked increase in the frequency and intensity of heat waves globally. According to the Intergovernmental Panel on Climate Change (IPCC, 2021), the average global temperature has risen significantly since the late 19th century, with projections indicating that the intensity and duration of heat waves will continue to increase. These extreme temperature events are characterized by prolonged periods of excessive heat, often accompanied by high humidity, which exacerbates their effects on human health.

The World Meteorological Organization (WMO) has reported that the number of heatwaves has doubled in the past few decades, with some regions experiencing unprecedented temperature rises (WMO, 2020). This increase in heatwaves events poses serious risks to public health, as prolonged exposure to high temperatures can lead to a range of heat-related illnesses.

Health Implications

Heat-related illnesses encompass various conditions, with heat exhaustion and heatstroke being the most severe. Heat exhaustion occurs when the body loses excessive amounts of water and salt through sweating, leading to symptoms such as heavy sweating, weakness, dizziness, nausea, and headache. If not treated promptly, heat exhaustion can progress to heatstroke, a life-threatening condition where the body temperature rises above 104°F (40°C), leading to confusion, seizures, and even death (Haines & Ebi, 2019).

In addition to direct heat-related illnesses, extreme heat can exacerbate existing health conditions, particularly cardiovascular diseases. Research indicates that high temperatures can strain the cardiovascular system, increasing the risk of heart attacks and strokes (Bell & Davis, 2020). A study by the American Heart Association found that for every 1°F increase in temperature, the risk of cardiovascular events rises significantly, particularly among individuals with pre-existing conditions (American Heart Association, 2020). Furthermore, high temperatures can lead to increased air pollution, compounding respiratory issues and triggering asthma attacks (McMichael & Lindgren, 2011).

Vulnerable Populations

Certain populations are disproportionately affected by heat waves, including the elderly, children, and individuals with pre-existing health conditions. The elderly are particularly vulnerable due to age-related physiological changes that impair the body's ability to regulate temperature (Haines & Ebi, 2019). Older adults are more likely to have chronic health issues, such as heart disease, which can be exacerbated by extreme heat.

Children are also at heightened risk, as their bodies are less efficient at cooling down than adults. Young children may not recognize when they are becoming overheated, leading to potentially severe outcomes if adequate precautions are not taken (Patz & Balbus, 2008). Additionally, low-income communities often lack access to air conditioning and other cooling resources, increasing their vulnerability during heat waves (Ramin & Sadler, 2009).

Other at-risk groups include outdoor workers, athletes, and individuals with disabilities. Outdoor workers, such as those in agriculture and construction, face increased exposure to high temperatures, leading to a higher incidence of heat-related illnesses (American Conference of Governmental and Industrial Hygienists, 2019). Similarly, athletes engaged in outdoor sports during extreme heat conditions are at increased risk for heat exhaustion and heatstroke.

Respiratory and Cardiovascular Diseases

Impact of Air Quality on Health

Air quality has a profound impact on public health, particularly as climate change exacerbates conditions that lead to air pollution. Increased temperatures, wildfires, and extreme weather events contribute to higher concentrations of harmful pollutants in the atmosphere. For instance, wildfires, which have become more frequent and severe due to climate change, release large quantities of particulate matter (PM) and other toxic substances into the air (Haines & Ebi, 2019). These pollutants can travel vast distances, affecting air quality far beyond the immediate vicinity of the fire.

Research has shown that exposure to particulate matter is directly associated with various health issues, particularly respiratory diseases. The World Health Organization (WHO) estimates that air pollution contributes to approximately 4.2 million premature deaths globally each year, with a significant proportion of these deaths attributable to respiratory diseases such as asthma and chronic obstructive pulmonary disease (COPD) (WHO, 2021). As climate change continues to worsen air quality through increased pollution and more frequent wildfires, the incidence of these health conditions is likely to rise.

Respiratory Issues

Respiratory diseases, particularly asthma and COPD, are among the most significant health impacts associated with air pollution and climate change. Asthma affects millions of individuals worldwide, with rising temperatures and increased allergens contributing to its prevalence. Higher temperatures can lead to extended pollen seasons and increased production of allergens, exacerbating asthma symptoms (Bell & Davis, 2020). Additionally, air pollutants, including ozone and particulate matter, can trigger asthma attacks and worsen the condition (Patz & Balbus, 2008).

Chronic obstructive pulmonary disease (COPD) is another critical concern linked to poor air quality. COPD, characterized by progressive respiratory symptoms and reduced airflow, is often caused by longterm exposure to harmful pollutants, including tobacco smoke and ambient air pollution. A study found that individuals living in areas with high levels of air pollution are at a significantly increased risk of developing COPD (McMichael & Lindgren, 2011). Furthermore, severe weather events can lead to temporary spikes in air pollution levels, further exacerbating respiratory conditions during and after such events (Ramin & Sadler, 2009).

Cardiovascular Impacts Linked to Climate Variability

The impact of climate change on cardiovascular health is another critical area of concern. Research indicates that climate variability, including extreme heat and poor air quality, is closely linked to increased cardiovascular morbidity and mortality. Elevated temperatures can place significant stress on

the cardiovascular system, leading to a higher incidence of heart attacks and strokes. A study published by the American Heart Association found that for every 1°F increase in temperature, the risk of cardiovascular events rises significantly, particularly among individuals with pre-existing conditions (American Heart Association, 2020).

Moreover, air pollution is a well-established risk factor for cardiovascular diseases. Long-term exposure to fine particulate matter and other pollutants is associated with increased rates of hypertension, heart attacks, and other cardiovascular conditions (Bell & Davis, 2020). The mechanisms underlying these associations include inflammation, oxidative stress, and the promotion of atherosclerosis, which can all be exacerbated by the effects of climate change (Haines & Ebi, 2019).

In summary, the interplay between climate change, air quality, and public health is complex but critical to understanding the rising incidence of respiratory and cardiovascular diseases. As air quality continues to deteriorate due to climate-related factors, proactive measures must be implemented to mitigate these health risks, particularly for vulnerable populations.

Vector-Borne Diseases

Changes in Habitats for Vectors

Climate change significantly alters the habitats of disease vectors such as mosquitoes and ticks, which are crucial in transmitting various infectious diseases. As global temperatures rise, the geographic range of many vector species is expanding, allowing them to thrive in previously inhospitable areas. Warmer temperatures can accelerate the life cycles of these organisms, increase their reproductive rates, and extend their active periods, thereby enhancing their potential to spread diseases (Patz & Balbus, 2008).

For example, the Aedes aegypti mosquito, a primary vector for dengue fever and Zika virus, has been reported to expand its range into higher altitudes and latitudes due to warmer temperatures (Haines & Ebi, 2019). Similarly, ticks, which transmit Lyme disease and other infections, are moving into new regions as they seek more favourable climatic conditions (McMichael & Lindgren, 2011). This shift in habitats poses significant public health challenges, as human populations in these newly affected areas may lack immunity to the diseases transmitted by these vectors.

Spread of Diseases

The spread of vector-borne diseases is closely tied to climate variability. Diseases such as malaria and dengue fever are highly sensitive to changes in temperature, humidity, and precipitation patterns. For instance, malaria transmission is most efficient in warm and humid conditions, which are increasingly becoming prevalent in many regions due to climate change. A study found that a 1°C increase in temperature could lead to a significant increase in malaria cases, particularly in higher-altitude regions that were previously less affected (American Heart Association, 2020).

Dengue fever, another notable vector-borne disease, has seen a marked increase in incidence and geographic distribution in recent years. Factors such as increased rainfall and higher temperatures contribute to the proliferation of Aedes mosquitoes and the viruses they carry. The World Health Organization (WHO) reported that the global incidence of dengue has increased dramatically over the past few decades, with over 390 million infections occurring annually (WHO, 2021). The expansion of dengue's geographic range is closely linked to climate change, as warmer temperatures and erratic rainfall patterns create ideal breeding conditions for mosquitoes.

Case Studies of Outbreaks and Climate Correlation

Several case studies illustrate the correlation between climate change and the emergence of vector-borne diseases. One significant example is the resurgence of malaria in the highlands of East Africa. Research indicates that rising temperatures and increased rainfall have created conducive conditions for the Anopheles mosquito, the primary vector of malaria (Haines & Ebi, 2019). In regions such as the Ethiopian highlands, where malaria was previously uncommon, increased transmission has been observed, leading to public health concerns.

Another compelling case is the spread of dengue fever in the Americas. Between 2010 and 2019, several countries, including Brazil and Mexico, experienced severe dengue outbreaks linked to climatic factors. A study conducted in Brazil found that the incidence of dengue cases was closely associated with temperature and rainfall patterns, with higher temperatures correlating with increased transmission rates (Patz & Balbus, 2008). The WHO has emphasized that the frequency and intensity of dengue outbreaks are likely to rise as climate change continues to influence environmental conditions conducive to vector proliferation.

Furthermore, the emergence of the Zika virus in the Americas in 2015-2016 highlights the role of climate in vector-borne disease outbreaks. The Aedes aegypti mosquito, which thrives in warmer conditions, played a critical role in the spread of the virus. Studies showed a strong correlation between increased temperatures, precipitation, and the incidence of Zika infections, emphasizing the need for ongoing surveillance and adaptation strategies to mitigate the impact of climate change on public health (McMichael & Lindgren, 2011).

Water and Food Security

Impact of Climate Change on Water Resources

Climate change poses significant threats to water security, which in turn affects food security worldwide. Changes in precipitation patterns, increased frequency of droughts and floods, and rising temperatures directly impact the availability and quality of freshwater resources. According to the Intergovernmental Panel on Climate Change (IPCC, 2021), climate change is projected to exacerbate water scarcity in many regions, particularly in areas already experiencing water stress. This situation is critical, as approximately 2 billion people currently live in water-scarce regions, and this number is expected to rise as climate change progresses (World Health Organization [WHO], 2021).

Droughts, which are becoming more frequent and severe due to climate change, can lead to significant reductions in water availability for agricultural practices. The United Nations has reported that droughts can severely impact crop yields and livestock production, leading to food shortages and increased prices (United Nations, 2020). Conversely, heavy rainfall and flooding can contaminate freshwater supplies, leading to waterborne diseases and further complicating food security (Patz & Balbus, 2008). Thus, the interplay between climate change, water availability, and food production creates a precarious situation for global food security.

Food Security Challenges

Food security is deeply intertwined with water availability, as agriculture relies heavily on consistent and quality water supplies. Climate change affects crop production through altered growing seasons, reduced yields, and increased pest and disease pressure. For example, rising temperatures can shorten the growing season for key crops such as wheat and corn, leading to lower yields and food shortages (Ramin & Sadler, 2009). Additionally, extreme weather events, such as hurricanes and floods, can devastate agricultural land, further exacerbating food insecurity.

The WHO (2021) highlights that food insecurity is not just a problem of quantity but also of quality. Climate change can lead to the deterioration of nutritional quality in crops, as higher carbon dioxide levels can reduce the concentrations of essential nutrients like protein, iron, and zinc in staple foods. This decline in nutritional quality poses serious health risks, particularly for vulnerable populations, including children and pregnant women.

Waterborne Diseases and Food Security

Water insecurity also has direct implications for public health, particularly through the increased risk of waterborne diseases. Contaminated water sources, exacerbated by flooding and poor sanitation facilities, can lead to outbreaks of diseases such as cholera and gastrointestinal infections (Haines & Ebi, 2019). These health issues further strain food security, as illness can reduce agricultural productivity and increase healthcare costs for affected populations.

In regions where water scarcity is prevalent, the competition for water resources can lead to social and political tensions, further destabilizing food systems. For instance, in parts of Africa and the Middle East,

conflicts over water resources have been linked to food insecurity and migration patterns as communities seek more stable living conditions (McMichael & Lindgren, 2011).

Mental Health Impacts of Climate Change

Psychological Effects of Extreme Weather Events

Climate change is increasingly recognized for its profound effects on mental health, stemming largely from extreme weather events and the anxiety associated with environmental changes. Natural disasters, such as hurricanes, floods, and wildfires, can cause immediate psychological trauma, leading to conditions such as post-traumatic stress disorder (PTSD), anxiety, and depression (Khanna & Dutta, 2021). For instance, studies have shown that individuals affected by Hurricane Katrina experienced longlasting mental health issues, with significant increases in PTSD symptoms among survivors' years after the event (Haines & Ebi, 2019). These psychological impacts can be exacerbated in communities with limited access to mental health resources, compounding the effects of the disaster.

Climate Anxiety and Eco-Anxiety

Beyond the immediate effects of disasters, the gradual and pervasive nature of climate change contributes to a phenomenon known as "climate anxiety" or "eco-anxiety." This refers to the chronic fear of environmental doom and the stress associated with the perceived threat of climate change (Patz & Balbus, 2008). As public awareness of climate change grows, many individuals experience feelings of helplessness and despair about the future of the planet, which can manifest as anxiety, depression, and a sense of loss (Khanna & Dutta, 2021). The psychological toll of witnessing environmental degradation—such as the loss of biodiversity, melting ice caps, and increasing natural disasters—can lead to a profound sense of grief and anxiety, particularly among younger generations who face an uncertain future.

Vulnerable Populations

Certain populations are particularly vulnerable to the mental health impacts of climate change. For example, children and adolescents are at a heightened risk due to their developmental stage; they may struggle to process the implications of climate change and its associated threats (McMichael & Lindgren, 2011). Additionally, marginalized communities—often facing socioeconomic challenges—may experience compound stressors related to climate change, such as displacement, loss of livelihood, and health disparities, leading to increased vulnerability to mental health issues (Haines & Ebi, 2019).

Policy and Adaptation Strategies for Climate Change and Health

Overview of Public Health Policies Addressing Climate Change

Effective public health policies are crucial for mitigating the health impacts of climate change. Governments and organizations are increasingly recognizing the need for integrated approaches that address both climate adaptation and public health. Policies aimed at reducing greenhouse gas emissions, enhancing community resilience, and improving access to healthcare services are essential components of a comprehensive strategy to protect public health (McMichael & Lindgren, 2011). The World Health Organization (WHO) emphasizes the importance of building health systems that can withstand climaterelated stresses, advocating for health adaptation plans as part of broader climate change strategies (WHO, 2021).

One significant policy framework is the Paris Agreement, which seeks to limit global warming to well below 2 degrees Celsius above pre-industrial levels. This framework underscores the necessity of international cooperation in addressing climate change and its health implications (IPCC, 2021). Public health professionals are increasingly involved in climate policy discussions to ensure that health considerations are integrated into climate action plans at local, national, and international levels.

Importance of Climate-Resilient Health Systems

Developing climate-resilient health systems is a critical adaptation strategy to protect against the health impacts of climate change. This involves strengthening healthcare infrastructure, training healthcare workers to recognize and respond to climate-related health issues, and improving data collection and analysis to inform decision-making (Haines & Ebi, 2019). For instance, establishing early warning

systems for heatwaves and extreme weather events can help prepare communities and healthcare providers to respond effectively, reducing morbidity and mortality associated with these events. Moreover, integrating mental health services into public health responses is vital, given the increasing prevalence of climate-related mental health issues. Policymakers must prioritize mental health support in disaster preparedness and recovery plans, ensuring that communities have access to necessary resources and support systems (Khanna & Dutta, 2021).

Case Studies of Successful Adaptation Initiatives

Several successful adaptation initiatives demonstrate the effectiveness of proactive policies in addressing climate-related health challenges. For example, in the United States, local governments have implemented heat action plans that include establishing cooling centers, increasing public awareness, and providing resources for vulnerable populations during extreme heat events (American Heart Association, 2020). These initiatives have proven effective in reducing heat-related illnesses and deaths, particularly among at-risk groups.

Internationally, countries like Bangladesh have developed comprehensive climate adaptation strategies that include improving water and food security, enhancing healthcare infrastructure, and promoting community engagement in disaster preparedness (Patz & Balbus, 2008). These efforts not only address the immediate health impacts of climate change but also build resilience in communities facing ongoing environmental challenges.

CONCLUSION

The increasing frequency and intensity of heatwaves due to climate change present a significant public health challenge. Heat-related illnesses, particularly heat exhaustion and heatstroke, pose serious health risks, especially for vulnerable populations such as the elderly, children, and individuals with chronic conditions. Effective public health strategies are essential to mitigate these risks, including community education, provision of cooling centers, and policies aimed at reducing heat exposure during extreme weather events.

The relationship between climate change and vector-borne diseases is complex and multifaceted. Changes in habitats for vectors, combined with shifting climate patterns, are facilitating the spread of diseases such as malaria and dengue fever. Case studies from various regions provide compelling evidence of this correlation, underscoring the urgent need for public health strategies that incorporate climate considerations into disease prevention and control efforts.

As climate change continues to pose significant threats to public health, policymakers must adopt comprehensive strategies that integrate health considerations into climate action plans. By developing climate-resilient health systems, enhancing public awareness, and implementing effective adaptation initiatives, communities can better prepare for and respond to the health impacts of climate change. Collaborative efforts among governments, public health organizations, and communities are essential to ensure a healthier, more resilient future in the face of climate change.

Addressing the health impacts of climate change requires a multifaceted approach that integrates public health, climate science, and community engagement. By implementing these recommendations, policymakers and public health officials can enhance resilience, protect vulnerable populations, and ensure a healthier future in the face of ongoing climate challenges.

Recommendations for Addressing the Health Impacts of Climate Change

To effectively mitigate the health impacts of climate change, comprehensive strategies are essential. The following recommendations aim to enhance public health resilience and address the multifaceted challenges posed by climate change:

1. Integrate Health into Climate Policies Ensure that public health considerations are integrated into national and local climate action plans. This includes assessments of health risks associated with

climate change and the incorporation of health resilience into climate adaptation strategies (McMichael & Lindgren, 2011).

2. Strengthen Climate-Resilient Health Systems Invest in healthcare infrastructure to withstand climate-related stresses. This includes improving facilities, training healthcare professionals to recognize and respond to climate-related health issues and developing early warning systems for extreme weather events (Haines & Ebi, 2019).
3. Promote Public Awareness and Education Launch community education campaigns to raise awareness about the health risks associated with climate change. These campaigns should target vulnerable populations and provide information on how to reduce risks during extreme weather events, such as heatwaves and floods (WHO, 2021).
4. Enhance Surveillance and Data Collection Improve data collection and analysis related to climate change and health. Establish surveillance systems to monitor the incidence of climate-related health issues, enabling timely responses and informed decision-making (Patz & Balbus, 2008).
5. Focus on Vulnerable Populations Develop targeted interventions for vulnerable populations, including the elderly, children, and lowincome communities. This includes ensuring access to healthcare resources, mental health support, and community engagement in disaster preparedness (Khanna & Dutta, 2021).
6. Implement Sustainable Agricultural Practices: Promote climate-smart agricultural practices that enhance food security and adapt to changing climate conditions. This includes investing in research for drought-resistant crops, improving irrigation systems, and promoting sustainable land use practices (Ramin & Sadler, 2009).
7. Enhance Water Resource Management Develop integrated water resource management strategies that address the impacts of climate change on water availability and quality. This includes investing in infrastructure for water conservation and wastewater management to ensure safe drinking water (Haines & Ebi, 2019).
8. Support Mental Health Initiatives Integrate mental health services into public health strategies addressing climate change. This includes providing resources for psychological support during and after extreme weather events and addressing the mental health impacts of climate anxiety (Khanna & Dutta, 2021).
9. Foster Interdisciplinary Collaboration Encourage collaboration between public health professionals, climate scientists, policymakers, and community organizations to develop comprehensive strategies that address the interconnectedness of climate change and health (McMichael & Lindgren, 2011).
10. Monitor and Evaluate Adaptation Strategies Implement mechanisms to monitor and evaluate the effectiveness of adaptation strategies in mitigating health impacts. Continuous assessment will help identify best practices and areas for improvement, ensuring that strategies remain effective in changing conditions (WHO, 2021).

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