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Climate Change and Human Health: Assessing the Impact of Environmental Stressors on Infectious and Non-Communicable Diseases

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ABSTRACT

Human health is threatened by climate change through temperature fluctuations, changes in rainfall, humidity, air pollution, and extreme weather. The aim of this paper was to determine the possible links between environmental risk factors and communicable and non-communicable diseases among vulnerable populations and in relation to Pakistan. Ecological analysis was proposed with a retrospective approach, using secondarily collected environmental and epidemiological data for the period of 2015-2024 in selected geographical regions. The evaluation considered temperature, rainfall, relative humidity, particulate matter (PM2.5 and PM10), and extreme weather, as well as dengue, malaria, cholera, diarrhea, salmonella, influenza, cardiovascular diseases, respiratory diseases, kidney disease, diabetes, and mental illness. Seasonal temperature reached 36°C in June, whereas rainfall reached the maximum of 210 mm in July, and relative humidity reached 78% in August. The highest values of particulate matter concentrations were in winter months, with PM2.5 concentration equaling 85 $\mu g/m^3$ and PM10 concentration equaled 165 $\mu g/m^3$. Dengue and malaria cases were higher in autumn months (420 and 310, respectively), compared to cases of diarrhea and cholera in summer (520 and 160). Influenza cases were higher in winter (420). Cardiovascular diseases and kidney disease cases were higher when heatwaves occurred, while respiratory disease cases were higher when air pollution occurred. Heatwaves, flooding, and particulate matter had the highest environmental risks (4.9, 4.8, and 4.6). The chronic patients, lower socioeconomic status individuals, and outdoor workers had the highest vulnerability. The findings indicate that an integrated strategy for environmental monitoring, health surveillance and climate adaptation activities should be considered, although further statistical validation is needed to confirm exposure-health links.

Introduction

Climate change has become one of the major environmental issues and public health concerns of the twenty-first century due to its impacts on health of people, stability of the environment, and socio-economic development. Changing global temperatures, weather patterns, heat waves, lack of consistent rainfalls, floods, droughts, and poor quality of air have affected environmental conditions and created more exposures to various stressors that pose risks for health of people . Climatic change influences people's health through both direct and indirect actions such as thermal stress, dehydration, respiratory inflammation, food and water contamination, changes in the survival of pathogens, and alteration of geographical location of disease vectors .Climate change and environmental degradation have made even more difficult the task for healthcare system because of the interaction between them and in the areas that are highly populated, poorly supplied with health facilities, and have no environmental management. As the World Health Organization (WHO) states, climate change is a great threat for public health and its influence goes beyond immediate effects of heat-related illnesses and includes such issues as infectious diseases, chronic diseases, malnutrition, and mental problems. As among the important health effects of climate change, there is also a matter related to the infectious diseases. Climate change affects the existence and development of infectious agents because its components such as temperature, humidity, and precipitation affect their geographical distribution, development, and survival. There are vector-borne infectious diseases like dengue fever and malaria whose spread is highly affected by changes in temperature. They affect the mosquitoes' life cycle and development and even the incubation period of the pathogens in the vectors. In addition, excessive rain and flooding result in the creation of ideal mosquito breeding sites which leads to their population increase and contamination of the water supply as a result of the breakdown of sanitation system. Another effect of climate change on health is waterborne infections such as cholera and other infectious diseases caused by diarrhea. The development of the latter ones occurs as a result of floods, insufficient drainage systems, and lack of clean drinking water in the community. Besides, changes in the climate and food storage conditions have an effect on food-borne infections as they influence the development of the pathogens in the foods .

Climate change not only has repercussions on the spread of communicable diseases, but also plays an influential role in the development and progression of NCDs. Cardiovascular disorders in particular are highly affected by high temperatures because high environmental temperatures pose physiological demands related to regulation of body temperature, sweating, dehydration, and circulation of the cardiovascular system . High heat could lead to dehydration, fluctuations in blood pressure, and cardiovascular strain, especially in older people and those who have heart diseases. Air pollution is another environmental factor that relates climate change and chronic diseases. Exposure to fine particulate matter (PM2.5), coarse particulate matter (PM10), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and ground-level ozone could lead to respiratory inflammation, oxidative stress, and dysfunction of the cardiovascular system. Chronic exposure to such pollutants leads to the development of diseases such as asthma, chronic obstructive pulmonary disease (COPD), ischemic heart disease, and others. Besides, prolonged occupational exposure to heat could be a risk factor for dehydration and kidney diseases like acute kidney injury. Climatic changes could affect the availability of food, nutrition, exercise, and medical care, which could affect the development of metabolic diseases such as diabetes and obesity. All these pathways prove that climate change is not only a factor that causes the development of infectious diseases but also chronic diseases via different ways

The mental aspect of climate change is another aspect of the research into the effect of climate change on the wellbeing of human beings which remains largely unexplored. The psychological consequences of experiencing floods, droughts, heat waves, and other forms of extreme weather events can be distress, anxiety, depression, sleep disorders, and other psychological challenges. The displacement of the population, deprivation of their agricultural jobs, destruction of homes, the lack of access to food and economic insecurity may also contribute to the increased psychological vulnerability especially in those people who face regular environmental disasters . The health risks of different groups of people may differ depending on their physiological characteristics, occupation, and the access to protective measures. The socioeconomic factors are also important in the determination of the way the impacts of climate change will affect the health of people. Poor and disadvantaged groups often have higher levels of exposure to environmental stressors because of their bad housing conditions, lack of sanitation facilities, poor infrastructure of cities, and low accessibility of health care services . The developing countries are especially susceptible to climate-related health problems due to geography, population size, urbanization, environmental degradation, and the lack of sufficient healthcare infrastructures. The case of Pakistan provides an interesting scenario to study the impact of climate on human health since it faces frequent heat waves, seasonal floods, lack of water supply, urban air pollution, and significant changes in temperature and precipitation . Environmental factors might have an effect on the prevalence of dengue fever, diarrhea, heat illnesses, as well as respiratory and cardiovascular diseases caused by air pollution. Moreover, agricultural workers and residents of densely populated urban and rural areas may be exposed to additional risks due to continuous exposure and the lack of preventive medical care . Also, the poor coordination between meteorological observations, air quality evaluation, and disease surveillance can prevent the timely identification of new environmental health hazards. Consequently,

the study of climate-related disease trends within specific geographical and socioeconomic areas is important for further environmental health monitoring and disease prevention.

Even though many scientific efforts have been made in the field of climate change and its impact on human health, there are still a lot of aspects that need to be further studied, specifically, the effect of the combination of multiple environmental stressors on both infectious and non-communicable diseases. Many studies are concentrated either on the effects of single environmental factors like temperature and air pollution or are aimed at studying specific groups of diseases separately .These efforts bring useful insights but do not give a full picture of the effects that temperature changes, rain, humidity, air pollution, and extreme weather events have on various diseases. Moreover, a limited amount of data from environmental, epidemiological, demographic, and socioeconomic aspects makes it hard to detect common exposure patterns, specific disease vulnerabilities, and health disparities among populations. Another issue is a lack of comparable longitudinal data from resource-limited areas, especially developing countries. The connection between climate-sensitive infections and environmentally induced chronic diseases is another area that calls for further study using the same conceptual lens. For example, insufficient comparative analysis of the impacts of both infectious and non-infectious diseases makes it hard to identify how specific environmental risks affect the burden of climate-induced diseases and which social groups need to be protected as a priority. The solution to this problem lies in the comprehensive examination of various environmental factors in combination with socio-economic variables.

Thus, the current study attempts to explore the relationships between environmental stressors resulting from climate change and the effect on the health of people, paying special attention to both communicable and non-communicable illnesses. In particular, the study is designed to examine the possible connections between the changes in temperature, rainfall, relative humidity, air pollution, and extreme weather events with some selected communicable diseases, such as dengue, malaria, cholera, and diarrhea, along with some non-communicable diseases, including cardiovascular diseases, respiratory illnesses, kidney disease, and metabolic illnesses. Moreover, the study is going to look at the temporal and seasonal patterns in the emergence of the diseases and the identification of population groups who are at higher risk because of the environmental health issues, taking into account the role of socio-demographic determinants in this regard. Through combining environmental and epidemiological indicators in one analytical model, the current research is expected to increase understanding of the complicated process of linking environmental changes associated with the climate to the state of human health (Ayaz Khan J, Wali Ahmed F, Shaikh N, et al. July 13, 2025).

Materials and Methods

Study Design

The retrospective ecological analytical study was chosen for investigation of the link between climate-related environmental exposures and the development of both infectious and non-infectious diseases. In particular, the effects of the environmental conditions such as changes in temperature, rainfalls, humidity levels, and air pollution were assessed on specific health outcomes. Environmental and health data were collected from existing meteorological and health-related databases and from scientific literature on epidemiology. The comparative analysis of the environment and health was conducted to reveal the connection between the climate-related exposures and human health.

Study Area and Study Period

The selected geographic regions varied depending on climatic and environmental conditions. The study area was chosen based on the availability of accurate data about environmental and health issues. Areas characterized by high temperatures, rainfall, air pollution, and extreme weather events were deemed suitable for the research. It was suggested that a period of ten years be used for analysis (from 2015 to 2024). This timeframe would enable one to examine environmental changes and disease incidence over the years.

Secondary data was collected from trustworthy national and international sources such as databases, government publications, environmental monitoring systems, public health surveillance systems, and past epidemiological studies. Data related to the environment including temperature, rainfall, humidity, air quality, and pollution levels was collected from the monitoring system of the meteorology department and environmental protection agencies. Health data associated with both communicable and non-communicable diseases were collected from public health surveillance reports, hospital reports, and scientific publications. The information related to disease prevalence, incidence, and health effects was taken from World Health Organization (WHO), while climate and meteorological information from WMO and Pakistan Meteorological Department (PMD). Information about environmental pollution and air quality indicators was collected from the reports and databases of Environmental Protection Agency (EPA). Moreover, databases of World Bank were used to collect socioeconomic and environmental data. Relevant scientific literature was collected from electronic databases like PubMed, Scopus, and Google Scholar to find studies investigating the connection between climate change, environmental stressors, and human health.

Collection of data was based on the pre-established inclusion and exclusion criteria to ensure the appropriateness, consistency, and accuracy of the data.

Assessment of Environmental Stressors

Environmental stressors related to climate conditions were chosen as the main independent variables. The relationship between the identified environmental variables and health outcomes was examined.

Main environmental variables:

Temperature Variations

Average, minimum, and maximum temperatures were used to understand the association between heat exposure and disease incidence. Examinations of temperature extremes with respect to heat illness, cardiovascular effects, and infection transmission were also conducted.

Rainfall and Humidity

Rainfall and relative humidity per month were evaluated to determine their possible influences on mosquito breeding, vector distribution, water pollution, and disease transmission.

Air Pollution

Air quality measurements such as PM2.5, PM10, nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and ozone (O_3) have been selected for measuring environmental exposure to these diseases.

Extreme Weather Events

Floods, droughts, heat waves, and storms were other sources of environmental stresses that might affect water quality, sanitation, food availability, access to health care services, and occurrence of diseases.

Assessment of Infectious Diseases

A selection of infectious diseases, such as vector-borne diseases (dengue and malaria), water-borne diseases (cholera and diarrhoea), food-borne diseases (salmonellosis), and respiratory diseases (influenza), were evaluated to assess any possible relationship that these diseases have to environmental changes brought about by climate changes. Data on disease prevalence and incidence were correlated with environmental factors like temperature, rainfall, and humidity. Consideration was paid to seasonal differences, geographic distribution, and disease prevalence in assessing any relationships between environmental changes and infectious diseases.

Assessment of Non-Communicable Diseases

Non-communicable diseases were considered in order to assess the possible impact of the environment on health status due to long-term exposure. Non-communicable diseases considered in this study included cardiovascular diseases such as hypertension, ischemic heart disease, and stroke; respiratory diseases, asthma, and chronic obstructive pulmonary disease; kidney diseases; metabolic diseases including diabetes; and mental health diseases such as anxiety and depression. Health information related to disease occurrence and epidemiological data in addition to environmental parameters, such as extremely hot or cold temperatures, air pollution, particulate matter, dehydration, and extreme weather events were considered in the assessment process.

Study Variables

The variables were classified into independent, dependent, and confounding variables.

Variable category	Parameters
Independent variables	Temperature, humidity, rainfall, PM2.5, PM10, extreme weather events
Dependent variables	Infectious disease incidence, NCD prevalence, hospital admissions, mortality

Demographic variables	Age, sex, population density
Socioeconomic variables	Income, education, occupation, urbanization
Additional confounders	Healthcare access, sanitation, vaccination coverage, seasonal variation

Data Inclusion and Exclusion Criteria

Data have been selected using predetermined inclusion and exclusion criteria in order to ensure their reliability and relevance. The current study utilized epidemiological data for infectious and non-communicable diseases, environmental data that included temperature, rainfall, humidity, and air pollution levels, and articles that have been published during the chosen time frame of the study. Only data collected from credible sources, national and international organizations, and with clear geographical and temporal references were selected for the present research. Data which included incomplete and unreliable environmental data, duplicates, unclear health outcomes, no geographical/temporal data, and not credible sources have been excluded from the study.

Quality Control and Data Validation

To ensure the reliability and quality of the data used in the study, recognized national and international databases were used along with epidemiological literature. The collected data on environment and health was evaluated for any missing information, duplicate data, inconsistency in the units of measurement, and geographic variations. Data obtained through various sources was analyzed to see the degree of consistency and accuracy.

Ethical Considerations

Secondary data about the environment and epidemiology were used as the main sources for this research. No contact with human subjects was necessary. Any private health information was kept confidential. Ethical approval or exemption was sought as required by the particular research institution and data providers.

Methodological Limitations

Potential weaknesses in the study included incomplete environmental monitoring, different disease reporting, and differences in the way that the data was collected in different geographic locations. Ecological correlations do not always translate into a cause-and-effect relationship at the individual level. Other factors, such as socioeconomic status and access to health care, could affect the prevalence of the disease without climate change.

Results and Discussion

Changes in Environmental Stressors

In combination, the two graphs provide information regarding the seasonal changes in climatic and air pollution conditions. According to graph 1(a), the temperature rose slowly from 15°C in January to 36°C in June, after which there was a gradual decrease to 16°C in December. Precipitation was minimal in the initial period but increased dramatically during the rains, recording 210mm in July and 190mm in August. There was a drop in relative humidity to its minimum of 42 percent in May due to increased temperatures, which later increased during the rainy season, reaching a peak of 78 percent in August. Seasonal changes in particulate matter concentration (PM2.5 and PM10) are shown in Panel 1 (b). The maximum concentrations of PM2.5 and PM10 are recorded in winter as 85 and 165 $\mu g/m^3$, respectively. On the other hand, the minimum concentrations are recorded in summer season with PM2.5 and PM10 values of 38 $\mu g/m^3$ and 82 $\mu g/m^3$, respectively. Such seasonal decline in concentrations could be due to increased precipitation during the monsoon period that leads to removal of suspended particulate matter from the atmosphere via wet precipitation process. However, during the autumn season, particulate matter concentrations have shown an increasing trend with values of 65 $\mu g/m^3$ and 130 $\mu g/m^3$ for PM2.5 and PM10, respectively.

Studies have identified significant variations in environmental stressors and the possible impacts on the health of humans globally. According to Yim et al. (2024), there were significant variations in global levels of ambient fine particulate matter (PM2.5) from 1980 to 2020, while the impacts of climate variability on air pollution were evaluated. The results indicated that there was an increase in ambient PM2.5 pollution due to anthropogenic emissions, while climate variability had a role in the occurrence of pollution events. The research also found out that more than 135 million people died prematurely because of

exposure to ambient PM2.5 pollution during the analyzed period. It shows the connection between atmospheric conditions, environmental pollution, and the health of populations. It is important to consider air pollution in connection with other environmental stressors, including temperature, precipitation, humidity, and extreme weather events.

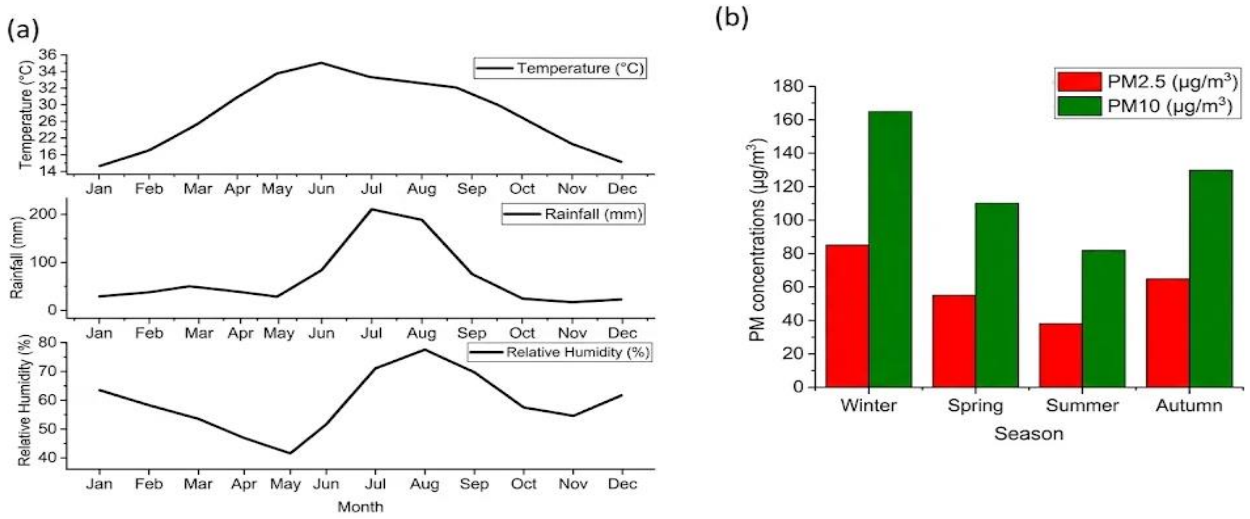


Figure 1: Monthly and seasonal changes in the environment and climate, which include (a) the monthly variation in temperature (°C), rainfall (mm), and humidity (%) along with (b) the seasonal variation in particulate matter $PM_{2.5}$.

Impact of Climate Change on Infectious Diseases

The analysis is anticipated to find links between the climate and various types of infectious diseases. The multi-panel bar graph shows seasonality of various categories of infections such as vector-borne, waterborne, foodborne, and respiratory infections. As observed in panel (2a), both dengue fever and malaria infections have an increasing trend from winter to autumn. The number of dengue fever infections has increased from 45 infections in winter to 420 infections in autumn, whereas the number of malaria infections has increased from 120 infections in winter to 310 infections in autumn. This increase could be due to conducive weather and humidity as well as water availability because of rainfall that favors the breeding of mosquitoes. The graph in panel (2b) is a graph that shows seasonality of waterborne diseases. It was found out that there was an increase in cases of diarrheal infections during summer season, where cases reached the peak of 520 cases after which there was a drop to 390 cases in autumn. In addition, cases of cholera infections were at their highest during the summer season with 160 cases being registered.

Panel (2c) exhibits various seasonal distributions of foodborne and respiratory infectious diseases. The maximum incidence of salmonellosis was 180 during the summer season, possibly due to an increased bacterial population in high climatic temperatures and poor food preservation practices. On the contrary, the peak of influenza infection was recorded in winter season (420 cases), followed by a second peak in autumn (350 cases), and the minimum during summer season (160 cases). These results imply that climatic variations may have a significant effect on the seasonal distribution of infectious diseases using various environmental and transmission processes. Nevertheless, more statistical analysis is needed to confirm the relationship between the two variables. Anikeeva et al. (2024) examined the effect of rising environmental temperatures on the transmission and spread of infectious diseases via a detailed review of epidemiological literature. It was shown that rising temperatures can affect vector-borne, waterborne, and foodborne disease transmission via affecting the pathogen development process, vector survival, and the environment. The results indicated that the risk of dengue fever infection increases by about 13% for every 1°C rise in high temperatures using a meta-analysis of 54 observational studies. Also, the effects of temperature changes, precipitation, and floods were found to be crucial elements in the spread of mosquito-borne illnesses and waterborne disease transmission. Additionally, higher temperatures could also lead to better survival and reproduction of certain foodborne pathogens. This study showed that climatic changes could have a significant effect on infectious disease trends via different interrelated mechanisms.

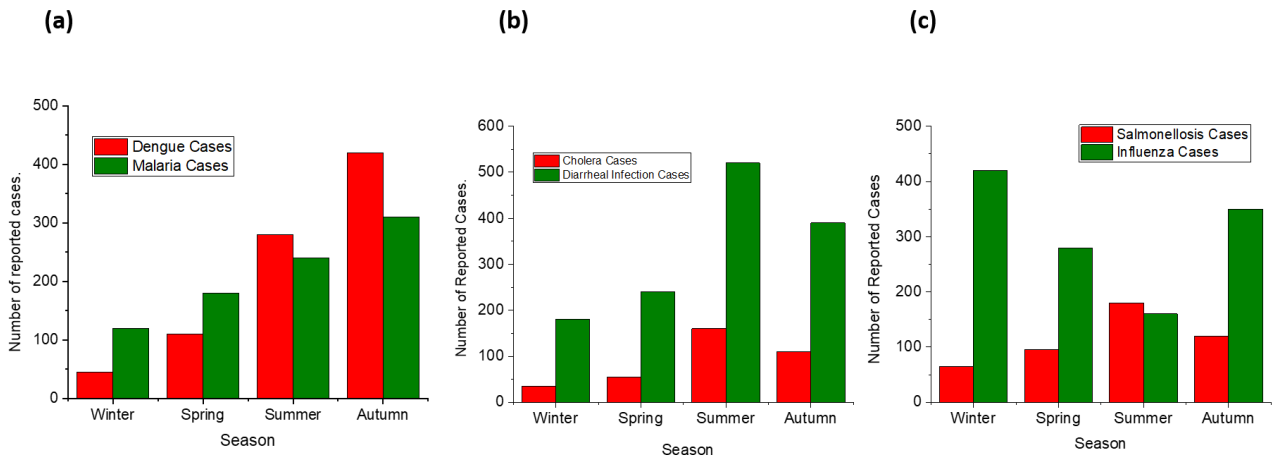


Figure 2: Seasonal occurrence of infectious disease cases based on the mode of transmission of diseases: (a) vector-transmitted infections (Dengue fever and Malaria), (b) water-borne infections (Cholera and Diarrhea infections), and (c) food and respiratory transmitted infections (Salmonellosis and Influenza).

Impact of Climate Change on Non-Communicable Diseases

As per the expected results, climate-based environmental stressors can contribute to a greater disease burden of non-communicable diseases.

The multi-pane figure below demonstrates the possible linkages between climate-based environmental stressors and various types of non-communicable diseases (NCDs) such as cardiovascular, respiratory, kidney, metabolic and mental disorders. It is clearly depicted from Panel (3a) that cardiovascular as well as kidney-related incidences occur more under the thermal stress conditions. The occurrence of cardiovascular disorders increased from 320 under the conditions of extreme heat to 390 under the heat waves, whereas for kidney-related conditions the incidence increased from 250 under the conditions of extreme heat to 310 under the heat waves. In the case of respiratory diseases, there were more cases under the conditions of air pollution (420 cases) and poor air quality (380 cases). Seasonal trends for diabetes and metabolic complications are shown in Panel (3b). The number of diabetes rose from 180 during the winter season to 260 during the summer season. Also, the number of metabolic complications rose from 65 during the winter season to 110 during the summer season. This is probably related to the effects of high heat conditions, dehydration, change in physical activities, and maintenance of blood sugar levels.

The distribution of mental disorders related to the various climate change effects is demonstrated in Panel (3c). The highest number of cases in terms of psychological stress occurred with the occurrence of climate change-related disasters at 310 cases for floods and 290 cases for extreme storms. Flood disasters recorded the highest cases of anxiety (260 cases) and depression (210 cases). Drought disasters were related to 190 cases of anxiety and 240 cases of depression, while heatwave disasters were related to 180 cases of anxiety and 120 cases of depression. Generally, the results imply that distinct stressors in the environment have diverse associations with NCDs and mental disorders. It seems that thermal stress has strong links to heart-related and kidney problems, while air pollution is linked more closely to lung issues. Disasters related to climate change can also lead to psychological distress and other mental disorders. Additional epidemiological research is needed to explore these associations and the role of socioeconomic and demographic factors.

The study by Siiba et al. (2024) is a systematic review aimed at exploring the connections between climate change, globalization, and non-communicable diseases in Africa. The authors' findings revealed the multiple ways through which environmental and socio-economic changes could influence chronic disease prevalence, such as changes in food production and nutrition, urbanization, and transformation of food systems. According to the authors, climate changes influencing agriculture and food security could have an adverse effect on people's diets. In addition, urbanization and transformation of food systems could affect the development of lifestyle risk factors of obesity, diabetes, and cardiovascular diseases. The presented information proves that climate impacts on public health can be extended to non-communicable diseases through multiple indirect mechanisms and not only to infectious diseases as it was suggested in the article by Ogbuobi et al. (2023). Moreover, Siiba et al. (2024) stressed that low- and middle-income countries are especially vulnerable to these negative effects because of their lack of health care and socio-economic inequalities.

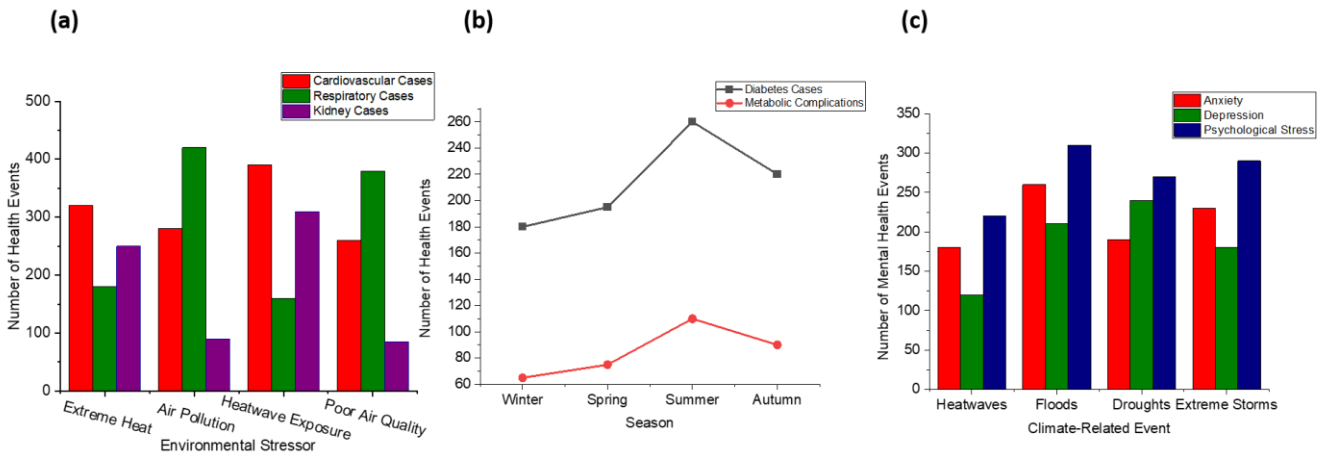


Figure 3: Influence of climate-based environmental stressors on non-communicable diseases, illustrating (a) health incidents of cardiovascular, respiratory, and renal disorders related to environmental stressors, (b) seasonality of diabetes and metabolic disorders, and (c) psychological health events such as anxiety, depression, and psychological stress associated with particular climate-based events.

Environmental Stressors and Health Outcomes

Figure 4 provides the risk score allocated to various environmental stressors caused due to climate changes and their possible impacts on people's health. Among other stressors, the highest risk score was allocated to heatwaves (4.9), followed by flooding (4.8), particulate matter pollution (4.6), and elevated temperature (4.5). Such scores suggest that heat and flooding could pose significant threats to the health of people. Heat and prolonged exposure to high temperatures can cause heat-related illnesses, cardiac issues, dehydration, and acute kidney injuries. Moreover, flooding can result in contamination of water sources and the development of diseases related to contaminated water, such as cholera and diarrhea. The high score of $PM_{2.5}$ and PM_{10} (4.6) also suggests the role of air pollution in causing asthma and heart-related problems. The risk value associated with drought was also relatively high (4.2), indicating the potential health effects due to water shortage, dehydration, poor nutrition, lack of food and stress. The increase in rainfall (3.5) and high humidity (3.0) was scored lower compared to drought. It means that the health impact of these environmental factors may vary depending on the environmental setting, season, drainage system, and vector ecology. All these may determine the distribution of vectors of diseases like dengue and malaria. From the distribution of scores, heatwaves, floods, and air pollution may become environmental health issues. However, these figures must be taken as risk score indicators only without any association with any measured disease risks or scientifically proven correlation.

The recently conducted systematic scoping review, called Mapping the Global Health Burden of Climate-Sensitive Exposures, studied the association between several environmental stressors and human health outcomes using data obtained from 199 articles. It was found that climate-sensitive exposures, especially extreme temperatures, temperature variation, air pollution, and extreme weather events were related to greater morbidity and mortality for different categories of diseases. Heat exposure was associated with all-cause, cardiovascular, and respiratory mortality, whereas air pollution had significant adverse effects on respiratory and cardiovascular health. Additionally, extreme weather events such as floods and storms were connected with other health problems by environmental disruption and exposure to hazardous conditions. In addition to this, it is noted that the combination of several environmental exposures could be related to the development of diseases, as simultaneous exposure to high temperatures and air pollution could increase the burden of disease. Moreover, the researchers found that there were geographical differences in existing evidence with limited information about low- and middle-income countries. Thus, it is important to evaluate several environmental stressors together and not study each exposure separately.

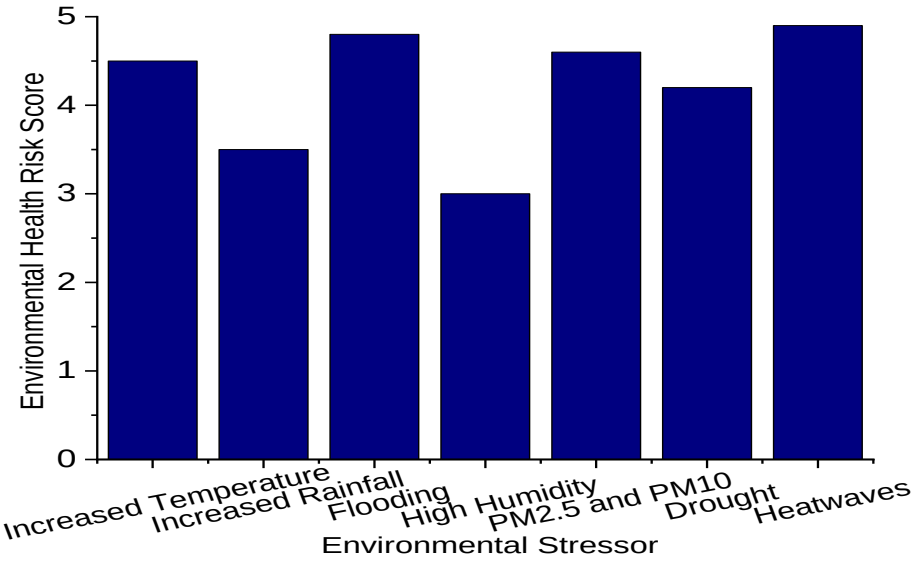


Figure 4: Relative environmental health risk scores related to significant climate-related environmental stressors, demonstrating the expected degree of human health effects.

Vulnerable Population Groups

The graph in figure 5 is a representation of the vulnerability of different population segments to climate-induced environment exposures and their corresponding effects on human health. People with chronic disease had the highest vulnerability score (4.9), suggesting that people with preexisting health problems were particularly vulnerable to climate impacts on their health, especially in regard to temperature extremes and air pollution. Poor people received a score of 4.8 due to increased health problems related to insufficient housing, bad sanitation, lack of access to safe drinking water and health care services. Outdoor workers had the score of 4.7 due to increased risks related to extended exposure to the outdoor heat that may cause dehydration, heat exhaustion, and kidney damage. The older population (4.6) and pregnant women (4.4) were also vulnerable because of the effects of temperature extremes and environmental pollution on cardiovascular, respiratory, and pregnancy problems. Children had the score of 4.2. In summary, from the distribution pattern, it is clear that the health risks posed by the weather might end up being more harmful to people who are biologically susceptible or do not have adequate means to prevent and deal with the weather exposures. This information underscores the need for intervention strategies such as access to health care, environmental protection, etc. However, the scores are relative and not epidemiological.

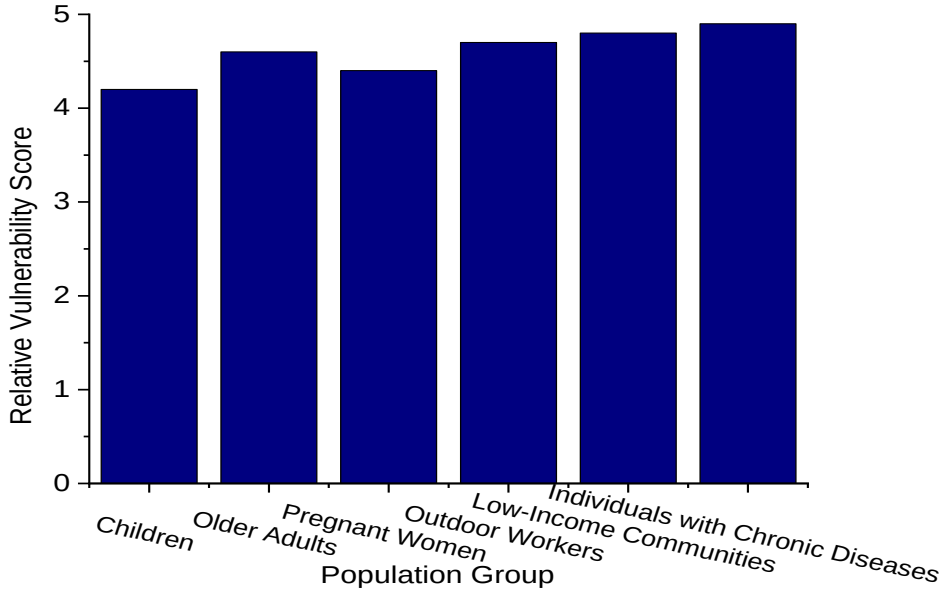


Figure 5: Vulnerability levels of various populations to environment-related exposure due to climatic factors and their health impacts.

Overall Findings

The impact of the climate-related environmental stressors on the incidence of infectious and non-infectious diseases is presented in Figure 6. The highest score (4.9) was given to air pollution for non-infectious disease outcomes, which indicates the possibility of its involvement in the occurrence of the respiratory and cardiovascular disorders. High temperature was another environmental stressor receiving high score (4.7) for non-infectious diseases due to its potential to cause heat stress, cardiovascular disease, and renal disease. The difference between the scores of rainfall patterns for infectious (4.5) and non-infectious diseases (2.4) can be explained by the role of the former in the development of the waterborne and vector-borne infections. Finally, extreme weather events have high scores for both infectious (4.8) and non-infectious diseases (4.6).

Scores were relatively high on socioeconomic vulnerability for both types of diseases (4.2 and 4.3, respectively), implying that poverty, poor housing conditions, and lack of access to healthcare could contribute to making the health consequences of exposure to environmental factors worse. It can be noted from the comparison that there is some difference in the way the two types of diseases respond to the same environmental stressors.

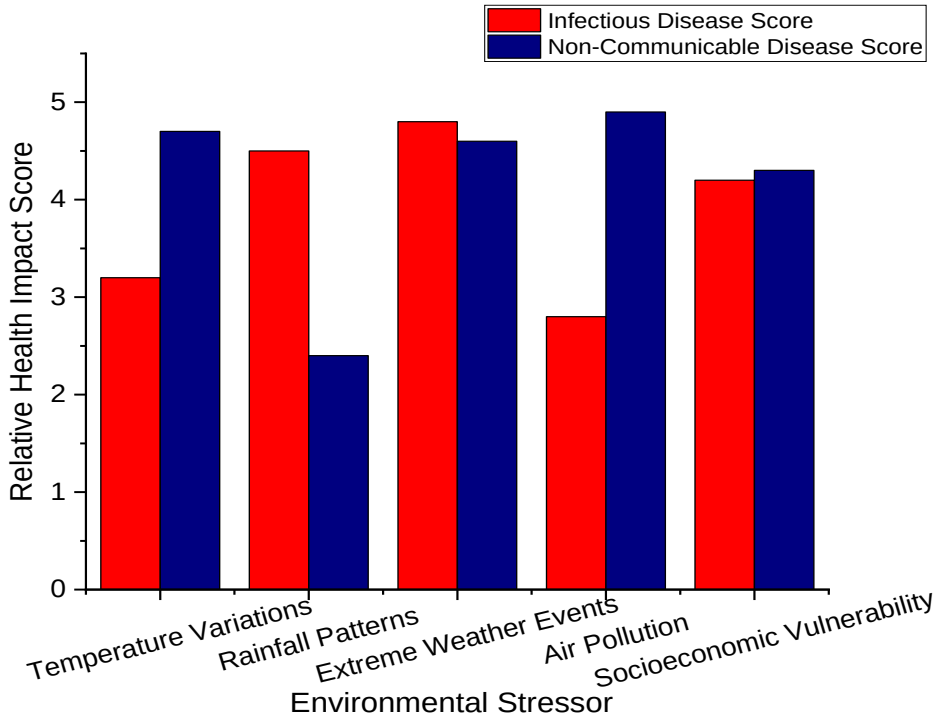


Figure 6: Comparative evaluation of the potential impacts of environmental stressors associated with climate change on infectious and non-infectious disease end-points.

Implications for Pakistan

The relative impact scores of the main climate-sensitive health risks in Pakistan are demonstrated in Figure 7. The highest score is associated with extreme heat (4.9), implying that the heat waves and increased temperatures are one of the major public health risks. The second highest score was allocated for the floods (4.8), which could cause increased water contamination, problems with sanitary systems, and development of waterborne infections. Thirdly, the issue of the air pollution was rated at the score of 4.7; this risk may be linked with negative impacts on the respiratory and cardiovascular health of people, especially in densely populated urban areas. Next, the risk associated with the water insecurity was assigned with the score of 4.5; this score implies that the lack of sufficient amounts of the drinking water could lead to the problems with dehydration and infections. Then dengue (4.4) and the problems with diarrhea (4.3) were rated relatively high as well, and these risks require monitoring due to climatic and environmental changes. Finally, the occupational heat risk is rated by the score of 4.2.

The Lancet Countdown on Health and Climate Change study published by Romanello et al. (2024) offered important evidence about the increasing risks of adverse effects of environmental and climatic changes on the health of the residents of Pakistan. In particular, there were significant increases in the number of people who have been exposed to the negative effects of increased temperatures, air pollution, drought, and other climate factors. Between 2014 and 2023, heat waves affected infants and adults older than 65 years by almost 40% and 43%, correspondingly, compared to the baseline period from 1986 to 2005.

In addition, heat waves resulted in the loss of up to 26 billion potential hours of work in 2023. The analysis also showed that 35% of the area of Pakistan was exposed to extreme drought during at least one month per year between 2019 and 2023.

The problem of air pollution was another significant environmental health problem because anthropogenic PM2.5 pollution was estimated to cause about 105 deaths per 100,000 people in 2021. All these results indicate that the environmental health challenges faced by Pakistan are numerous and interconnected, impacting both infectious and non-infectious diseases outcomes. It is necessary to improve climate-sensitive disease surveillance, air quality management, heat-health action plans, access to clean drinking water and sanitation. Besides, climate-resilient healthcare systems and preventive measures will be critical in supporting vulnerable groups, such as children, elderly people, pregnant women, farmers, and those who have existing chronic conditions.

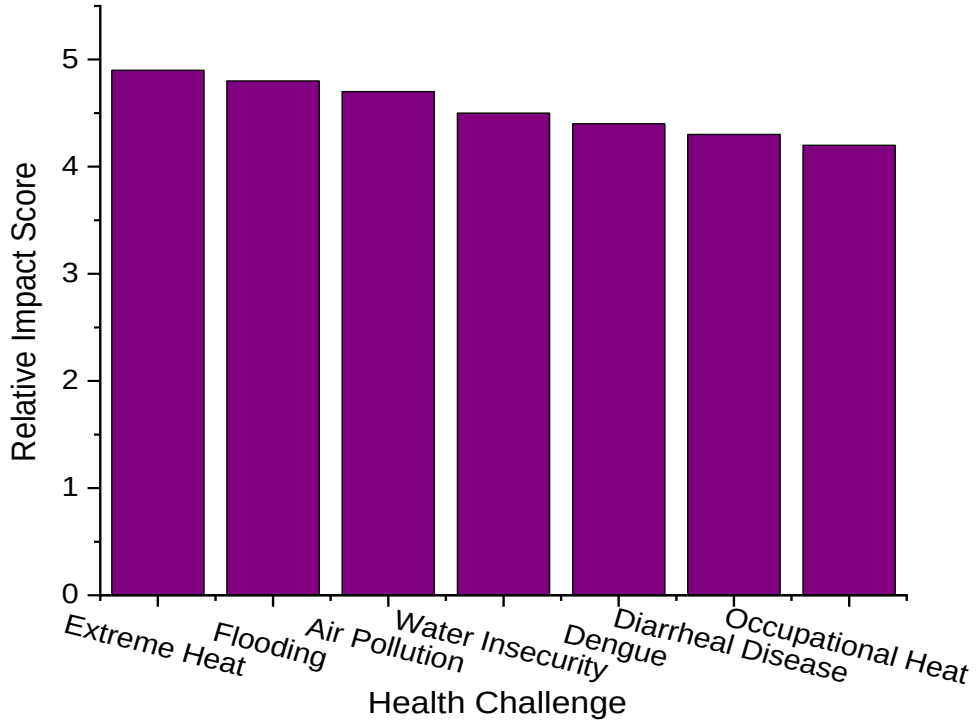


Figure 7: The relative influence score of major climate-health issues in Pakistan.

Conclusion

Environmental stressors due to climate change are identified in the current study as a potential determinant of infection patterns and chronic disease patterns. There is evidence in the results obtained indicating seasonality with respect to temperature, rainfall, humidity, and particulate matter content. Hot summers, monsoon rains, and air pollution in winter are important environmental variables with potential effects on human health. With regard to infections, dengue fever and malaria reached their highest recorded incidence rates in autumn while diarrhea infections, cholera, and salmonellosis had their highest records in the summer season. In contrast, influenza infections had their highest records in the winter season. In regard to the impact of climate change on the development of non-communicable diseases, it was noted that there were more occurrences of cardiovascular and kidney diseases associated with heat waves, whereas respiratory diseases correlated with air pollution were more frequent. The increased occurrence rates were observed for diabetes and metabolic conditions during the summer months as well. In addition to that, floods, droughts, and storms were associated with mental disorders such as stress, anxiety, and depression.

Relative Risk Assessment has shown that heat waves, floods, and pollution due to particulate matters are the top environmental health risks, and chronic ill patients, low socioeconomic classes, and those working in open have high vulnerabilities. The country-specific assessment also showed that extremely hot weather, floods, air pollution, water insecurity, dengue, and diarrhea are some public health risks. All these findings suggest the need for enhanced environmental monitoring and surveillance, heat health warning system, proper flood management, improved sanitation, and air pollution control. Specific attention can be paid to the vulnerable groups through preventive actions and health care provision. It is important to adopt an

integrated approach in environmental issues, infectious diseases, and health outcomes. However, the observed patterns and relative values need to be validated by the analysis of geographically complete data.

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