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Impacts of Climate Change on Respiratory Health, Case of Asthma: A Comprehensive 24-Year Review (2000 To 2023) of Current Trends and Future Perspectives

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Abstract Climate change, recognized as one of the major challenges of our time by the United Nations, poses an unprecedented threat to global health. This scientific article examines the multiple facets of the impact of climate change on respiratory health, with a particular focus on asthma. Through a detailed review of existing literature over the past 24 years, we explore the complex relationships between climate variations, environmental factors, and respiratory diseases. We analyze data from various sources, including epidemiological studies, epidemiological models, and public health surveys. In addition to providing the current assessment of the impact of climate change on asthma, this review explores future perspectives. The results show an increasing correlation between these climate changes and the worsening of asthma symptoms, as well as an increase in asthma-related hospitalizations. Furthermore, potential scenarios include an intensification of extreme weather events, variations in allergen distribution, and changes in air quality, all of which have the potential to exacerbate the challenges already posed by asthma. The implications of these emerging trends underscore the crucial importance of developing adaptation and mitigation strategies. Multidisciplinary approaches, involving healthcare professionals, climate scientists, and policymakers, are necessary to devise sustainable solutions aimed at protecting respiratory health in the face of the challenges posed by climate change.

Keywords: *climate change, respiratory health, asthma, current trends, future perspectives*

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1. Introduction

According to the United Nations and its Intergovernmental Panel on Climate Change (IPCC), climate change is one of the major global challenges of our time due to its unprecedented scale and worldwide impact. Greenhouse gas emissions significantly alter the planet's climate, with human activities considered the primary cause of these emissions [1,2]. The United Nations Framework Convention on Climate Change, in its first article, defines climate change as "a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods."

The increased frequency of obstructive respiratory diseases in recent years, especially asthma, can be partly explained by changes in the environment, with a growing presence of chemical triggers (particulate matter and gaseous components such as nitrogen dioxide and ozone) and biological triggers (aeroallergens) in the atmosphere. In allergic individuals, aeroallergens stimulate airway sensitization, inducing symptoms of bronchial asthma. Considering that the last four decades have been consistently warmer than previous ones, and 15 of the 16 hottest years recorded occurred after 2000 [3,4], climate change compels human societies and organizations to address and adapt to the ongoing changes, as some of these changes remain inevitable. It is essential that health-related issues engage the research and policymaking community. In addition, although west African region has a high burden of respiratory diseases, including asthma, there is a lack of comprehensive data on the prevalence, triggers, and management of these conditions. Understanding the interplay between climate change and respiratory health is crucial for developing effective strategies to mitigate the impacts and improve healthcare outcomes in the face of changing environmental conditions.To justify this, we will review the health effects of climate change on respiratory infections in general and asthma in particular.

2. Methodology

We conducted a comprehensive literature review to identify relevant articles related to climate change and health, focusing on respiratory infections and asthma. Keywords such as "Climate Change" " Respiratory infections," "Asthme," "Modeling" and "Air pollution" were used in both French and English articles between 2000 and 2023. The search was conducted on Google Scholar, web of sciences and Pubmed, resulting in the identification of 41 relevant studies.

Only studies that were released between 2000 and 2023 were included in our search (figure1).

41 articles related to our topic were found. After inclusion and exclusion criteria, 30 articles were selected for the review.

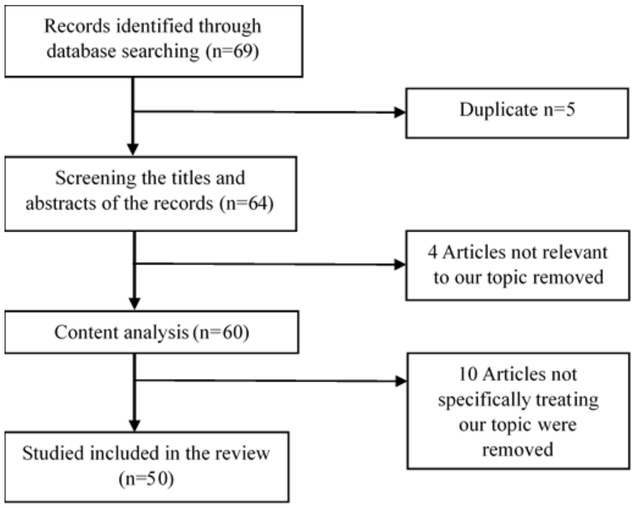

Figure 1. review methodology using inclusion and exclusion criteria with PRISMA

3. Results and Discussion

If Hippocrates' medical approach provided scientific support for hypotheses about a potential relationship between climate and health, nowadays, this relationship appears increasingly certain. According to the statement by Dr. Margaret Chan, Director-General of the World Health Organization (WHO), on World Health Day in April 2009, "Climate change is attacking the foundations of public health and giving us a glimpse of the challenges, we will face on a large scale. Furthermore, climate change directly jeopardizes health."

3.1. Theoretical Approach

Bioclimatology, defined as the science that deals with the relationships between climate and all living organisms, is increasingly sought after by policymakers, populations, and businesses due to the negative impact of climate change on health. Numerous studies have revealed that climate changes affect ecosystems and contribute to the emergence and re-emergence of many diseases. According to the World Health Organization [5], climate disruption influences the social and environmental determinants of health, such as air quality, safe drinking water, an adequate food supply, and housing security. Furthermore, the WHO [5] emphasizes that heatwaves directly contribute to mortality through cardiovascular or respiratory diseases, especially among the elderly. For instance, during the summer heatwave of 2003 in Europe, more than 70,000 additional deaths were recorded. Additionally, [5] point out that climate disruption in the coming decades will lead to a significant increase in the number of people exposed to health risks. According to the Intergovernmental Panel on Climate Change (IPCC), the next decades are expected to see an intensification of heatwaves, floods, droughts, and storm winds. These phenomena have severe consequences for population health.

[6] propose the idea that the vulnerability of a population (demographic structure, prevalence of pre-existing medical conditions, acquired factors like immunity, and genetic factors) or a region is the sum of all risks and protective factors that ultimately determine whether a group or region experiences adverse health issues. [7] argue that if health were a producible good, its production would be considered an investment compensating for the consumption of capital due to lifestyle and aging. According to them, the specification of health production functions determines how to allocate limited resources among other health inputs to achieve the greatest possible increase in health levels. This idea is also supported by [8] who agreed that a health production function demand shows how health inputs interact to produce a specific level of health and how health status changes if the health inputs used and their combination change. [9] estimated that health investment is obtained through the provision of curative medical services and individual efforts, especially in preventive measures.

In the same line of thought, [10] stated that improved health investments result in greater labor productivity due to improved physical and mental conditions and a reduction in the number of productive days lost due to illness. [11] considered in his health capital model that individuals react as both consumers and producers of health. He assumed that health production occurs through a health production function where health is determined by the consumption of medical care and other goods, with health inputs acting as investments that influence the depreciation rate of the health stock. Similarly, the author argued that rational individuals maximize the utility of their health by optimizing the management of their health stock throughout their lives.

3.1.1. Direct Mechanisms of Climate Change on Health

Temperature is the most direct factor influencing the impact of climate change on health. The relationship between mortality and temperature is generally characterized as a U-shaped curve, with high mortality at both low and high temperatures for most causes of death [12]. These temperature effects on mortality vary from one city to another and from one population to another over a given period, demonstrating the phenomenon of adaptation within certain societies [13]. The threshold at which the risk of death increases, known as the optimum thermal range (typically between 15 and 25°C), varies among populations. For instance, Southern European populations are more sensitive to the effects of cold than those in the North, while the Northern populations are more susceptible to heat. Specific studies focus on the risks posed by climate change to homeless populations, which are highly exposed to high temperatures and extreme weather events. These populations are also more vulnerable due to frequent chronic illnesses, social isolation, and a lack of mobility means [14]. The effects of high temperatures on the mortality of socially disadvantaged populations have been studied [15].

Regarding the duration of the effects, the effects of low temperatures generally manifest 21 days after exposure to low temperatures, while high temperatures show an effect after three days [16]. An American study [17]. demonstrates that the duration of exposure itself, beyond the immediate effect of high temperature on mortality, reveals an additional effect related to the duration of the heatwave, detectable after four consecutive days of heat. The slower decrease in temperatures in urban centers than in surrounding areas after a heatwave or during the night explains the amplification of health effects observed in urban heat islands, becoming a concern in a context where 68% of the global population will live in urban areas by 2050 [18]. It is also important to examine the impact of successive heatwaves as, with climate change, the warm season will start earlier and end later [19].

In addition to dehydration and hyperthermia, more direct biological effects also concern the cardiovascular, respiratory, endocrine, immune, and nervous systems. Adverse impacts of high temperatures on mental health have been identified [20], with the most consistent associations found for suicide rates [21] in numerous studies across different continents [22]. An effect of high temperatures on violent behavior has also been documented [23], possibly linked to disruptions in sleep and the endocrine system. While evolution has endowed the body with heat response mechanisms, their efficiency is limited, and they globally fatigue the organism. In a more chronic context, current research highlights that an increase in temperature combined with ultraviolet radiation could additively or synergistically increase the development of skin cancers.

3.1.2. Indirect Mechanisms of Climate Change on Health

The indirect effects of climate change are generally associated with the animal and plant kingdoms, the consequences of extreme climate change events, air pollutants, and rising sea levels. The anticipated health impact of climate change is linked to the alteration of the geographical distribution of vector-borne diseases. While some diseases, such as malaria, have not garnered unanimous agreement among researchers regarding the effect of climate change on transmission rates or geographical spread [24,25], others, like Lyme disease—a bacterial illness transmitted by ticks whose habitat is expanding [26] are likely influenced by climate change. The same holds for the West Nile virus [27] or dengue fever [28], transmitted by mosquitoes whose territories are expected to expand under the influence of climate change. The potential impact of climate change on Chikungunya and Zika viruses remains likely, with climate change extending the transmission zone. On another note, ocean warming favors the proliferation of certain bacteria, altering the geographical distribution of cholera epidemics [29]. Some researchers also raise concerns about the release of viruses and bacteria from permafrost thawing [30], including viruses that have been dormant for tens of thousands of years [31].

The plant kingdom is also a significant factor in the health impact of climate change. High temperatures and extreme climate events such as floods and droughts lead to decreased agricultural yields, malnutrition issues, and stunted growth in children in heavily agricultural communities. Increased atmospheric carbon dioxide negatively affects the micronutrient composition of various cereals [32] and enhances the proliferation of algae containing foodborne toxins, releasing toxic gases upon decomposition [33]. Furthermore, ocean acidification due to anthropogenic carbon dioxide absorption threatens marine life [34], impacting tsunami and hurricane resilience. This also affects zooplankton, a fundamental component of the food chain [35], and poses a risk of destabilizing communities and countries heavily dependent on fishing. The tripling of pollen allergies in France over the past two decades is attributed to early springs, causing increased pollen quantities, while allergenic plants like ragweed expand their distribution range [36].

With the interaction between climate and pollutant dispersion, as well as chemical reactions between atmospheric compounds, climate change will also impact the atmospheric concentration of certain pollutants influencing human health. Climate change increases ozone concentration in polluted regions, especially in urban areas, and besides their immediate health impact, increasingly common wildfires emit atmospheric pollutants and may become a significant source of particle emission and growth [37]. The 2010 summer heatwave in Moscow exemplified a heatwave episode coinciding with a peak concentration of suspended particles generated by wildfires around the city. Moreover, climate change will increase the frequency of sand and dust storms, with both local and global effects on air quality, associated with short and long-term respiratory problems [38].

Finally, rising sea levels will result in flooding with negative consequences for mega-cities at sea level with populations exceeding 10 million, especially given current projections anticipating a sea-level rise of 26 to 82 cm by the end of the present century [39].

3.2. Empirical Approach

Climate change poses a fundamental threat to human health, impacting the physical environment and all aspects of natural and human systems, including socio-economic conditions and the functioning of health systems. It is thus a "threat multiplier," potentially undermining decades of efforts and progress in health. The sixth assessment report of the Intergovernmental Panel on Climate Change estimates that up to 3.6 billion people live in highly vulnerable conditions to the impacts of climate change. Low-income countries, lower-middle-income countries, and small island developing states face the most severe health consequences of climate change, despite contributing the least to historical global emissions [40]. Multiple scientific assessments have highlighted diverse and substantial effects of climate change on human health and well-being and various data suggest that measures to reduce climate change have beneficial effects on public health [41]. These overall findings have led two distinct Lancet commissions (The Lancet Commission Report 2022 on Climate Change and Health) to conclude that climate change represents the greatest threat to global health [42] and the greatest global health opportunity of the 21st century. Ongoing research continues to capture the attention of researchers, aiming to quantify the current and future effects of climate change on human health.

Indeed, [43] report the results of a comprehensive multinational survey involving 4,654 healthcare professionals, examining their perspectives on climate change as a human health issue. In line with previous research, the survey participants, according to the authors, widely understood that climate change is occurring and caused by humans. They considered climate change a significant and growing cause of health damage in their respective countries and felt responsible for educating the public and policymakers about the consequences of these changes. [44] assess the impact of climate change on the health and well-being of populations in the Hindu Kush Himalayan region. The study results indicate that climate change exacerbates infectious diseases, non-communicable diseases, malnutrition, and trauma. Urgent adaptation and mitigation measures are therefore necessary to protect vulnerable populations in the region. In addition, the study demonstrate that the expanded spatial distribution and increased incidence of Chikungunya and dengue over the last decades in the Hindu Kush Himalayan region are attributed to climate change. [45] conduct in-depth semi-structured interviews with 22 residents of the Golden Horseshoe region in southern Ontario between August 2010 and January 2011. The interviews cover individual and community health, climate change, as well as facilitators and barriers to behavior change, to assess the impact of climate change on community health. Few participants acknowledged the role of the environment in the context of individual and community health. However, when asked about health concerns specific to their community, environmental issues were frequently mentioned. Health effects as possible impacts of global environmental change were mentioned by 77% of participants when asked, but this link was not described in great detail or in the context of the impact on their communities or themselves. [46] examine the relationships between climate impacts and health effects, providing examples of community-level adaptation measures currently implemented in northwest Alaska. The results show that climate change increases vulnerability to injuries, diseases, mental stress, food insecurity, and water insecurity. Northwest communities apply both specific and appropriate adaptation approaches. [47] assess the current situation in Ethiopia regarding environmental issues, climate change, and health. The research was conducted through a comprehensive review of available secondary data and interviews with key informants from various national organizations involved in climate change adaptation and mitigation activities. The results reveal that climate change-related health issues, such as mortality and morbidity due to floods and heatwaves, vector-borne diseases, waterborne diseases, meningitis, and respiratory diseases related to air pollution, are increasing in Ethiopia. Sensitive systems such as agriculture, health, and water have been affected, and the effects of climate change will continue to amplify without appropriate adaptation and mitigation measures. [48] study the impacts on health and social protection systems in the UK from extreme weather events under climate change conditions. The extreme weather events considered include heatwaves, cold waves, and floods. Using a structured review method, the authors examine evidence regarding currently observed and anticipated future impacts of extreme weather conditions on health and social protection systems, as well as the potential for preparedness and adaptation measures to enhance resilience. They highlight several general conclusions likely to have international relevance, even though the review focused on the UK situation. Extreme weather events impact the functioning of health services due to their effects on built, social, and institutional infrastructures supporting health and healthcare, as well as changes in service demand due to the impact of extreme weather events on human health. The American Thoracic Society (ATS), in collaboration with George Mason University, surveyed a random sample of ATS members to assess their perceptions, clinical experiences, and preferred policy responses to climate change. An email containing an invitation from the ATS president and a link to an online survey was sent to 5,500 randomly selected ATS members; up to four reminder emails were sent to non-respondents. Responses were received from members in 49 states and the District of Columbia (n = 915); the response rate was 17%. The geographic distribution of respondents reflects that of the sample. Survey estimate confidence intervals were ±3.5% or less. The results indicate that a large majority of ATS members concluded that climate change is happening (89%), caused by human activity (68%), and relevant to patient care ("a lot" / "a moderate amount") (65%). A majority of respondents indicated that they were already observing the impacts of climate change on their patients' health, most often in the form of increased severity of chronic diseases due to air pollution (77%), allergic symptoms due to exposure to plants or molds (58%), and extreme weather conditions. [49] through a quantitative survey of 130 households in the city of Ziguinchor, sought to analyze the impacts of climate change. Among its results, it found floods during the rainy season and an increase in temperature. These factors lead to an increase in malarial morbidity, acute respiratory infections, high blood pressure, and diarrheal diseases.

3.3. Modeling and Climatic and Environmental Determinants of Asthma

Asthma is a chronic inflammatory disorder of the respiratory tract that affects individuals of all ages worldwide. Chronic inflammation is associated with airway hyperreactivity, leading to recurrent episodes of wheezing, breathlessness, chest tightness, and cough, especially at night or early in the morning. The disease is prevalent in all age groups [50] and affects approximately 300 million people globally, causing 250,000 deaths annually. Environmental factors such as allergens, air pollution, or climate change can exacerbate the disease, as can infectious factors like viruses and bacteria. When uncontrolled, asthma can impose severe limitations on daily life and, at times, prove fatal.

Chronic respiratory diseases (CRDs), primarily asthma and chronic obstructive pulmonary disease (COPD), are influenced by a wide range of environmental, climatic, and socio-economic factors [51]. Epidemiological studies have convincingly explained the association between CRD morbidity and various individual-level risk factors, such as particulate matter, temperature, and poverty. For instance, [52] examine spatial associations between asthma/COPD morbidity and determinants using ordinary least squares (OLS) and geographically weighted regressions (GWR). The study considers hospital records collected in Kandy's secondary and tertiary care hospitals from 2010 to 2014 as the dependent variable. Potential risk factors (explanatory variables) are identified in four distinct classes: 1) meteorological factors, 2) direct and indirect air pollution factors, 3) socio-economic factors, and 4) characteristics of the physical environment. Exploratory regression evaluates all possible combinations of explanatory variables, with OLS models revealing around 55% variation in asthma and 62% in COPD occurrences, while GWR models show 78% and 74% variation, respectively. Relative humidity, proximity to roads (0 to 200 m), road density, wood burning for fuel, and altitude play crucial roles in forecasting asthma and COPD morbidity. Local and global regression models are important for assessing spatial relationships, with local models showing better predictive capacity for non-stationary relationships than global models.

[53] evaluate the relationship between hospital admissions for asthma and several environmental variables in continental Portugal using spatial data from remote sensing and spatial modeling. Five environmental variables are considered: air temperature near the surface (Ta) from the Moderate Resolution Imaging Spectroradiometer (MODIS) temperature profile; relative humidity (HR) from interpolated meteorological station data; vegetation density from the MODIS Normalized Difference Vegetation Index (NDVI); and spatiotemporal estimates of nitrogen dioxide (NO2) and particulate matter less than 10 µm (PM10), both from land use regression (LUR) models based on air quality station data. Districts are grouped into three categories based on their percentage of urban coverage, and municipalities are chosen as the sampling unit to assess the relationship between hospital admission rates for asthma and environmental variables by season for the years 2003-2008. In the most urbanized group, Ta, NDVI, and NO2 showed consistent relationships with asthma throughout the seasons (Pearson correlation coefficients ranging from 0.351 to 0.600, -0.376 to -0.498, and 0.405 to 0.513, respectively). Associations in other groups were very weak or nonexistent. Urban coverage percentage influences the environment-asthma relationship, suggesting that asthmatic individuals in highly urbanized areas with sparse vegetation are at greater risk of severe asthma attacks leading to hospitalizations.

[54] examine risk factors associated with asthma at the age of 7 in a high-risk cohort participating in a randomized controlled trial on primary prevention of asthma. Indoor exposures were characterized before birth and at 2 weeks, 4, 8, 12, 18, and 24 months after birth and again at 7 years. Nasal scrapings for respiratory viruses were conducted at the same intervals during the first 2 years. At the age of 7, children were assessed by a pediatric allergist and underwent allergy skin tests. Logistic regression analysis was undertaken to assess the effect of exposures on asthma for the entire cohort, adjusting for group allocation. In addition to a lower risk of asthma in the intervention group, a higher prevalence of asthma at the age of 7 was found in males, those with positive family histories of asthma in the mother, father, or older siblings, and in children residing in Winnipeg. After adjusting for intervention group allocation and baseline factors, significant environmental risk factors during the first year included dog ownership and respiratory syncytial virus infection detected at 12 months, while maternal smoking was protective. Dog ownership was a significant risk factor during the second year but strongly correlated with dog ownership in the first year. Environmental exposures during the seventh year were not associated with asthma at the age of 7. Maternal smoking in the seventh year was associated with a reduced risk of asthma at the age of 7. Early-life exposures were more important determinants than those in later years, suggesting a "window of opportunity" for intervention measures.

[55] examine the relationship between the prevalence of asthma symptoms in adolescents living in urban centers in Latin America and socio-economic and environmental determinants measured at the ecological level. The prevalence of asthma symptoms was obtained from the International Study of Asthma and Allergies in Childhood (ISAAC) Phase III. A hierarchical conceptual framework was defined, and explanatory variables were organized into three levels: distal, intermediate, and proximal. Weighted linear regression models were performed between asthma prevalence and selected variables. Asthma prevalence was positively associated with the Gini index, water supply, and homicide rate, and inversely associated with the Human Development Index, overcrowding, and adequate sanitation. This study provides evidence of the potential influence of poverty and social inequalities on current wheezing among adolescents in a complex social context such as Latin America.

[57] aim to identify socio-economic, environmental, psychosocial, family-related, and lifestyle factors associated with self-reported asthma symptoms in Brazilian adolescents. This cross-sectional study uses data from the 2012 PeNSE survey on a sample of 109,104 adolescents. The analysis includes socio-economic conditions, demographic characteristics, lifestyle, family context and dynamics, psychosocial indicators, smoking, and exposure to violence. The outcome variable was the self-assessment of asthma symptoms in the last 12 months. The prevalence of wheezing was 22.7% (21.5–23.9). After adjusting for gender, age, and variables from higher hierarchical levels, exposure to violence (feeling unsafe at school, frequent bullying, exposure to fights with firearms) and physical aggression by a family adult showed the strongest environmental associations with self-reported

asthma symptoms. For psychosocial indicators of mental health and social integration, feelings of loneliness and sleep problems were the most important factors, and among individual behavioral factors, the most significant associations were found for tobacco consumption.

4. Conclusion

The world is increasingly vulnerable to the impacts of climate change in terms of food security and health. This is particularly true due to inherent issues in terms of geography, demographic pressure, and limited infrastructure. As the impacts of climate change intensify, issues related to food security and health will also increase unless effective adaptation programs are implemented. To date, interventions appear to have had limited success while the topic continues to garner attention in the research and policymaking community.

Given the rapidly accumulating evidence of the numerous significant health risks posed by current climate change, our review clearly highlights the relative lack of research on the subject in developing countries in general and particularly in Togo.

Furthermore, although the health sector in Africa is also vulnerable and affected by climate change, disease modeling appears to be underdeveloped, rendering early warning systems for climate-sensitive diseases, especially respiratory ones, nearly non-existent or ineffective.

Given this consideration, it is imperative for African nations to expeditiously establish climate-health early warning systems grounded in epidemiological forecasting models that integrate climate data. This endeavor aims to enhance the adept management and vigilant surveillance of climate-sensitive ailments, notably respiratory diseases like asthma.

References

[1] Costello A, Abbas M, Allen A, et al. Managing the health effects of climate change. Lancet and University College London Institute for Global Health Commission. Lancet. 2009; 373: 1693–1733. [Crossref] [PubMed] [Web of Science ®], [Google Scholar].

[2] Mora C, Spirandelli D, Franklin EC, et al. Broad threat to humanity from cumulative climate hazards intensified by greenhouse gas emissions. Nat Clim Chang. 2018; 8: 1062–13. [Crossref] [Web of Science ®], [Google Scholar].

[3] Stocker TF, Qin D, Plattner G-K, et al. Climate change 2013: the physical science basis. Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change. Cambridge: Cambridge University Press, 2013.

[4] Cole S, Jacobs P. NASA, NOAA analyses reveal 2019 second warmest year on record. Washington: National Aeronautics and Space Administration, 2020.

[5] WHO. Climate change and health [Internet]. 2018 [cited 2020 Oct 27]. Available from: https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health. [Google Scholar].

[6] Balbus, J. M., & Malina, C. (2009). Identifying Vulnerable Subpopulations for Climate Change Health Effects in the United States. Journal of Occupational and Environmental Medicine, 51(1), 33–37.

[7] Zweifel P., Felder S. and Andreas Werblow A. (2004). Population Ageing and Health Care Expenditure: New Evidence on the "Red Herring". The Geneva Papers on Risk and Insurance. Issues and Practice, Vol. 29, No. 4, pp. 652-666. Stable URL: http://www.jstor.org/stable/41952787.

[8] Armstrong B. Models for the relationship between ambient temperature and daily mortality. Epidemiology 2006; 17: 624-31.

[9] Baldwin JW, Dessy JB, Vecchi GA, Oppenheimer M. Temporally compound heat wave events and global warming: an emerging hazard. Earths Future 2019; 7: 411-27.

[10] Benmarhnia T, Kihal-Talantikite W, Ragettli MS, Deguen S. Small-area spatiotemporal analysis of heatwave impacts on elderly mortality in Paris: A cluster analysis approach. Sci Total Environ 2017; 592: 288-94.

[11] Burke M, González F, Baylis P, et al. Higher temperatures increase suicide rates in the United States and Mexico. Nature Climate Change 2018; 8: 723-9.

[12] Gasparrini A, Armstrong B. The impact of heat waves on mortality. Epidemiology 2011; 22: 68-73. 22. Li D, Bou-Zeid E. Synergistic interactions between urban heat islands and heat waves: The impact in cities is larger than the sum of its parts. J Appl Meteor Climatol 2013; 52: 2051-64.

[13] Kidd SA, Greco S, McKenzie K. Global climate implications for homelessness: A scoping review. J Urban Health 2021; 98: 385-93.

[14] Borrell C, Mari-Dell'Olmo M, Rodriguez-Sanz M, et al. Socioeconomic position and excess mortality during the heat wave of 2003 in Barcelona. Eur J Epidemiol 2006; 21: 633-40.

[15] Pascal M, Wagner V, Corso M, Laaidi K, Ung A, Beaudeau P. Heat and cold related-mortality in 18 French cities. Environ Int 2018; 121: 189-98.

[16] Gasparrini A, Guo Y, Hashizume M, et al. Temporal variation in heat-mortality associations: A multicountry study. Environ Health Perspect 2015; 123: 1200-7.

[17] United Nations. World urbanization prospects. The 2018 revision. New York: United Nations, 2019.

[18] Woodward A, Ebi KL, Hess JJ. Commentary: Responding to hazardous heat: think climate not weather. Int J Epidemiol 2021; 49: 1823-5.

[19] Hansen A, Bi P, Nitschke M, Ryan P, Pisaniello D, Tucker G. The effect of heat waves on mental health in a temperate Australian city. Environ Health Perspect 2008; 116: 1369-75.

[20] Thompson R, Hornigold R, Page L, Waite T. Associations between high ambient temperatures and heat waves with mental health outcomes: a systematic review. Public Health 2018; 161: 171-91.

[21] Page LA, Hajat S, Kovats RS. Relationship between daily suicide counts and temperature in England and Wales. Br J Psychiatry 2007; 191: 106-12.

[22] Anderson CA, De Lisi M. Implications of global climate change for violence in developed and developing countries. In: Forgas J, Kruglanski A, Williams K, eds. The psychology of social conflict and aggression. New York: Psychology Press, 2011.

[23] Hay SI, Cox J, Rogers DJ, et al. Climate change and the resurgence of malaria in the East African highlands. Nature 2002; 415: 905-9.

[24] Pascual M, Ahumada JA, Chaves LF, Rodo X, Bouma M. Malaria resurgence in the East African highlands: temperature trends revisited. Proc Natl Acad Sci USA 2006; 103: 5829-34.

[25] Lindgren E, Jaenson TGT. Lyme borreliosis in Europe: influences of climate and climate change, epidemiology, ecology and adaptation measures. Copenhagen: World Health Organization Regional Office for Europe, 2006.

[26] Harrigan RJ, Thomassen HA, Buermann W, Smith TB. A continental risk assessment of West Nile virus under climate change. Glob Chang Biol 2014; 20: 2417-25.

[27] Naish S, Dale P, Mackenzie JS, McBride J, Mengersen K, Tong S. Climate change and dengue: a critical and systematic review of quantitative modelling approaches. BMC Infect Dis 2014; 14: 167.

[28] Escobar LE, Ryan SJ, Stewart-Ibarra AM, et al. A global map of suitability for coastal Vibrio cholerae under current and future climate conditions. Acta Trop 2015; 149: 202-11.

[29] Hueffer K, Drown D, Romanovsky V, Hennessy T. Factors contributing to anthrax outbreaks in the circumpolar North. Ecohealth 2020; 17: 174-80.

[30] Legendre M, Bartoli J, Shmakova L, et al. Thirty-thousandyear-old distant relative of giant icosahedral DNA viruses with a pandoravirus morphology. Proc Natl Acad Sci USA 2014; 111: 4274-9.

[31] Myers SS, Zanobetti A, Kloog I, et al. Increasing CO2 threatens human nutrition. Nature 2014; 510: 139-42.

[32] Grattan LM, Holobaugh S, Morris JG, Jr. Harmful algal blooms and public health. Harmful Algae 2016; 57: 2-8.

[33] Hoegh-Guldberg O, Mumby PJ, Hooten AJ, et al. Coral Reefs under rapid climate change and ocean acidification. Science 2007; 318: 1737-42.

[34] Doney SC. The dangers of ocean acidification. Sci Am 2006; 294: 58-65.

[35] Hamaoui-Laguel L, Vautard R, Liu L, et al. Effects of climate change and seed dispersal on airborne ragweed pollen loads in Europe. Nat Clim Chang 2015; 5: 766-71.

[36] WHO. Urgent health challenges for the next decade [Internet]. 2020 [cited 2020 Oct 27]. Available from: https://www.who.int/news-room/photo-story/photo-story-detail/urgent-health-challenges-for-the-next-decade. [Google Scholar].

[37] Dreyer, H., Grischke, J., Tiede, C., Eberhard, J., Schweitzer, A., Toikkanen, S. E., Stiesch, M. (2018). Epidemiology and risk factors of peri-implantitis: A systematic review. Journal of Periodontal Research.

[38] Cao A, Esteban M, Valenzuela VPB, et al. Future of Asian deltaic megacities under sea level rise and land subsidence: current adaptation pathways for Tokyo, Jakarta, Manila, and Ho Chi Minh City. Curr Opin Environ Sustain 2021; 50: 87-97.

[39] WHO. Climate change and health [Internet]. 2018 [cited 2020 Oct 27]. Available from: https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health. [Google Scholar].

[40] Watts N, Adger WN, Agnolucci P, et al. Health and climate change: policy responses to protect public health. Lancet. 2015; 386: 1861–1914. [Crossref] [PubMed] [Web of Science ®], [Google Scholar].

[41] Costello A, Abbas M, Allen A, et al. Managing the health effects of climate change. Lancet and University College London Institute for Global Health Commission. Lancet. 2009; 373: 1693–1733. [Crossref] [PubMed] [Web of Science ®], [Google Scholar].

[42] Michael Brubaker, James Berner, Raj Chavan and John Warren (2011) Climate change and health effects in northwest Alaska, Global Health Action, 4: 1.

[43] Cardwell, FS, Elliott, SJ Making connections: do we link climate change to health? A qualitative case study from Canada. BMC Public Health 13, 208 (2013).

[44] Michael Brubaker, James Berner, Raj Chavan and John Warren (2011) Climate change and health effects in northwest Alaska, Global Health Action, 4: 1.

[45] Cardwell, FS, Elliott, SJ Making connections: do we link climate change to health? A qualitative case study from Canada. BMC Public Health 13, 208 (2013).

[46] Fischer D, Thomas SM, Suk JE, et al. Climate change effects on Chikungunya transmission in Europe: geospatial analysis of vector's climatic suitability and virus' temperature requirements. Int J Health Geogr 2013; 12: 51.

[47] Curtis, S., Fair, A., Wistow, J. et al. Impact of extreme weather events and climate change on health and social welfare systems. Environ Health 16 (Suppl. 1), 128 (2017).

[48] Gasparrini A, Guo Y, Hashizume M, et al. Temporal variation in heat-mortality associations: A multicountry study. Environ Health Perspect 2015; 123: 1200-7.

[49] Lancet. 2020; Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019; 396 (10,258): 1204-22.

[50] Gobler CJ. Climate change and harmful algal blooms: insights and perspective. Harmful Algae 2020; 91: 101731.

[51] Kim Y, Kim H, Gasparrini A, et al. Suicide and ambient temperature: a multi-country multi-city study. Environ Health Perspect 2019; 127: 117007.

[52] Lin MJ, Torbeck RL, Dubin DP, Lin CE, Khorasani H. Climate change and skin cancer. J Eur Acad Dermatol Venereol 2019; 33: e324-5.

[53] Sanz-Barbero B, Linares C, Vives-Cases C, Gonzalez JL, Lopez-Ossorio JJ, Diaz J. Heat wave and the risk of intimate partner violence. Sci Total Environ 2018; 644: 413-9.

[54] Terjung, W.H. (1966) Physiologic Climates of the Contentious United States: A Bioclimatic Classification Based on Man. Annals of the Association of American Geographers, 5, 141-179.

[55] Turley C, Eby M, Ridgwell AJ, et al. The societal challenge of ocean acidification. Mar Pollut Bull 2010; 60: 787-92.

[56] United Nations. Global issues: climate change [Internet]. 2016 [cited 2020 Oct 26]. Available from: https://www.un.org/en/sections/issues-depth/climate-change/index.html [Google Scholar].

[57] World Health Organization. Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s [Internet]. World Health Organization; 2014 [cited 2020 Oct 27]. Available from: https://apps.who.int/iris/handle/10665/134014 [Google Scholar].