CHAPTER
50

Ozone depletion: causes and solutions

https://doi.org/10.56238/alookdevelopv1-050

Andréa de Melo Santos
Master's graduate program in development of environmental processes – UNICAP, 50050-900 Recife-Pe, Brazil.
Orcid: https://orcid.org/0009-0006-6790-695X
E-mail: andrea.santos@unicap.br

Fátima de Cássia de Athayde Borille
Postgraduate program master's degree in development of environmental processes – UNICAP, 50050-900 Recife-Pe, Brazil.
Orcid: https://orcid.org/0009-0003-5622-7095
E-mail: fatima.2022602130@unicap.br

Felipe Casa Nova Furtado
Postgraduate program master's degree in development of environmental processes – UNICAP, 50050-900 Recife-Pe, Brazil.
Orcid: https://orcid.org/0009-0005-4441-8972
E-mail: felipe.2022602149@unicap.br

Eliana Cristina Barreto Monteiro
Full teacher at ICAM-TECH School. University Catholic of Pernambuco – UNICAP and the University of Pernambuco – UPE
Orcid: https://orcid.org/0000-0003-0842-779X
E-mail: eliana.monteiro@unicap.br

Galba Maria Campos-Takaki
Full teacher at ICAM- TECH School. University Catholic de Pernambuco – UNICAP, 50050-900 Recife-Pe, Brazil.
Orcid: https://orcid.org/0000-0002-0519-0849
E-mail: galba.takaki@unicap.br

ABSTRACT
Since the Industrial Revolution, atmospheric carbon emissions have been more pronounced, due to the burning of fossil fuels that intensify the greenhouse effect and are currently contributing to the increase in temperature, leading to long-term global warming of the planet. The harmful interference of man on the biogeochemical cycles, especially carbon, transfers carbon from the biosphere to the atmosphere, as well as his competence in the removal of forest areas and other communities that act sequestering carbon from the atmosphere, resulting in the surplus of this gas, leading to global warming. Carbon dioxide, as well as other gases (methane, nitrous oxide, chlorofluorocarbons, and water vapor) act as greenhouse gases by seizing heat. All this heat retained in the terrestrial globe, interacts with the atmosphere and the ocean, influencing climate change, such as increased temperature and precipitation. Consequently, there is an increase in the temperature of the planet that has been melting the glaciers and increasing the sea level. Island nations and littoral countries are more exposed to feeling the consequences of rising sea levels. Another consequence of the imbalance of the greenhouse effect is related to the emergence and aggravation of some diseases such as skin cancer, and cataracts, among others, requiring the incessant search for solutions through scientific and technological development, combined with policies to minimize the current environmental crisis.

Keywords Global warming, greenhouse effect, greenhouse gases, diseases, skin cancer, cataract.

1 INTRODUCTION

Since the industrial revolution, the widespread use of commercial energy—sold to users and usually produced on a large scale by burning fossil fuels, hydroelectric, and nuclear power plants, as opposed to the energy associated with biomass collected and used by individual households—has increased every year, with the annual growth rate being about 2 percent. The period of fastest growth began after World War II when global consumption was only one-tenth of current levels (BAIRD, 2002).

The use of energy is directly related to industrialization, a fact observed with the increase in global energy consumption in the second half of the 20th century mainly due to industrial expansion and the increase in the standard of living in developed countries.

The increase in energy use is related to population growth, geographical conditions, and climate, especially in Brazil, considering the sources of water and appropriate relief for the increase in the cost of energy. In this context, the Gross Domestic Product (GDP), has been the most important factor in total energy consumption, according to studies conducted in the area, in which the ratio of energy to GDP generally increases when the country begins to industrialize (BAIRD, 2002).

As a result, the race of industrialized countries in the search for their energy supply and sufficiency is great, remembering that fossil fuels are not renewable sources, therefore, it imposes a limit to the use that drives it and promotes, including, the remarkable race for "black gold" (oil), in addition to the creation of strategies aimed at improving its domestic production and search for new alternatives as substitution/complementation to imports and the known limit of sources Usual. These alternatives constitute the contemporary theme of energy production, which several countries have set as a goal, including Brazil.

However, the alternatives are not only found in the segment of substitution by renewable sources, but in the demand for less polluting energy sources that contribute to the reduction of global warming, caused mainly by the release of CO_2 from the burning of fossil fuels destroying the ozone layer. The destruction of the ozone layer can lead to the passage of UV radiation, which has shorter wavelengths and large concentrated energy, being the most harmful to health. In this sense, with global warming significant impacts can occur on human health, because the UV rays formed can penetrate the skin and cause burns, in addition to having enough energy to ionize atoms and accelerate certain chemical reactions. And yet, there may be an increased incidence of respiratory and cardiovascular diseases due to air pollution, increased transmission of infectious diseases due to rising temperatures can cause climatic changes, with worsening of mental health problems due to stress caused by extreme weather events.

2 OZONE LAYER AND GREENHOUSE EFFECT

The ozone layer and the greenhouse effect are two important atmospheric phenomena that have been the subject of discussions about the health of our planet. The ozone layer is part of the layer of the atmosphere, this layer is located at 25km of altitude, and its main function is to filter sunlight preventing much of the UV radiation from reaching the Earth's surface (MADRONICH, 1993).

The greenhouse effect is a naturally occurring phenomenon on our planet and is responsible for regulating the temperature on Earth. Greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane

(CH_4), and water vapor retain some of the radiation that is emitted by the sun on the earth's surface in the form of heat. The greenhouse effect is fundamental for the maintenance of the ideal temperature for life on Earth, without the presence of this effect, the average temperature of the planet would be very low and difficult for the survival of many species (PETIT et al, 1999; Forster et al., 2007).

3 GLOBAL WARMING

However, human activities have negatively affected these two phenomena. Activities such as the burning of fossil fuels, accelerated industrialization, burning and the use of products that release CFC have caused more radiation to be retained in the earth causing an abnormal increase in the temperature of the earth's surface (MENDONÇA, 2007), causing what we know as global warming.

This global warming has brought several impacts on biodiversity (Lovett, 2019). The reduction of the ozone layer can cause health problems such as skin cancer and cataracts (KIRSCHBAUM et al., 2017).

4 OZONE DEPLETION: CAUSES AND SOLUTIONS

Greenhouse gases suffer the action of UV radiation, releasing free radicals, which in turn will attack the ozone molecules present in the ozone layer, causing a rarefaction of this gas forming what is known as a "hole in the ozone layer" exposing the earth to a higher incidence of UV rays (MOLINA et al., 1974). Greenhouse gas emissions need to be drastically reduced to avoid irreversible damage to the planet and our health (IPCC., 2018).

5 THE EFFECTS OF OZONE DEPLETION ON HEALTH

The processes that cause environmental changes affect the health of human beings directly or indirectly, and the magnitude of this impact is proportional to the reach of the population, the commitment, and the degree of reversal of the damage caused. Society, regionally or globally, can also be affected cumulatively - as occurs through the dumping of chemical contaminants in the set of ecosystems (BRASIL, 2021).

Some processes of global change have a systemic character and affect the ozone layer, one of the great cycles of the biosphere, corroborating its decrease, and exposing the population to risk factors and health problems (BRASIL, 2021).

The effects of this decrease on human health are worrisome and have been the subject of studies by researchers around the world and demonstrates significant implications for human health since it can trigger or aggravate several diseases. (REHMAN et al., 2019).

The morbidity and mortality resulting from climate warming would ultimately be related to six different factors, all presenting interactions with each other, namely: sea level rise, meteorological paroxysms, heat aggressions, effects on reproduction, air pollution, and nutrition (BESANCENOT, 2001).

The consequences of these actions on ecosystems act on the process of health, disease, and well-being of humanity, causing the emergence of new diseases, worsening of infectious diseases and increase in chronic non-communicable diseases, deterioration of the current food system with increased hunger and malnutrition, hyper-urbanization, microbial resistance, climate migrations and conflicts over natural resources, among others, according to the Institute of Advanced Studies of the University of São Paulo (IEA-USP). To illustrate these relationships, Figure 1 presents a flowchart that represents the interaction between human activity and its impacts on the ecosystem, which affect human health.

Figure 1 - Flowchart representing the interaction between human activity and its impacts on the ecosystem, affecting human health.

Source: Self-authored

In this context, Horton et al. (2014) published manifest calling attention to the need to move from a public health policy, limited to small domestic actions, to a planetary health policy.

The launch of the publication of the report entitled "*Safeguarding human health in the Anthropocene epoch: report of The Rockefeller Foundation–Lancet Commission on planetary* health" by the Rockefeller Foundation and the scientific journal The Lancet, further spread the concept of planetary health, which is referred to as the achievement of the highest possible standard of health, well-being, and equality throughout the world, through judicious attention to the human systems –

political, economic and social – that shape the future of humanity and the Earth's natural systems (WHITMEE et al. 2015).

More recently, the Planetary Health Alliance was created based at the Harvard T.H. Chan School of Public Health – which consists of a consortium of more than 350 universities, non-governmental organizations, research institutes, and government entities from more than 60 countries around the world, committed to understanding and addressing the impacts of global environmental change on human health and well-being, gathering efforts for the advancement of the health of the planet, aiming to rescue sustainability and healthy human life from an increasingly integrative, transdisciplinary and global perspective (PLANETARY HEALTH ALLIANCE, 2021).

We can see how much the Anthropocene action, through deleterious human activities, is causing the illness of the ecosystems, resulting in the compromise of Planetary Health.

6 AIR POLLUTION AND EFFECTS ON HUMAN HEALTH

With distinct meanings and effects, greenhouse gases and air pollution are indirectly related. Global warming can cause other phenomena of climate change and increase the concentration of air pollutants, causing health problems and about 5 million deaths per year worldwide (LIMA and HAMZAGIC, 2021).

According to the Pan American Health Organization (PAHO) (2019), air pollution is considered a global public health crisis, affecting the health of people of all ages and in all parts of the world, both in urban and rural areas. A study conducted in China showed that exposure to air pollution can reduce life expectancy by up to 5.5 years (GAO et al., 2017).

PAHO (2019) reports that air pollution in conjunction with household pollution was responsible for about one in eight deaths worldwide in 2016, totaling seven million deaths. Among the victims, about 543,000 children under the age of 5 and 52,000 children aged 5 to 15 years were attributed to the effects of air pollution at home. In addition, household air pollution through cooking activities and air pollution account for more than 50% of acute lower respiratory tract infections in children under the age of 5 in low- and middle-income countries. Of the deaths attributed to the effects of air and household pollution worldwide in 2016, 9% were in children (SILVA et al., 2021). According to Ritchie and Roser (2022), in Brazil, the mortality rate due to air pollution is approximately 5%, and in 2019, about 27 out of every 100,000 inhabitants lost their lives because of diseases related to air pollution. The increase in global temperature has had a significant impact on health, especially respiratory diseases such as asthma, bronchitis, and pneumonia. According to a report released by the World Health Organization (WHO), increased air pollution and climate change have contributed to aggravating these diseases. Additionally, the increase in temperature can cause

dehydration and electrolyte imbalance, further intensifying the symptoms of these respiratory diseases (BOSCOLO, 2019).

Especially in children, the effects of air pollution can be even more severe due to the particularities inherent to the age group itself related to behavioral, environmental, and physiological factors, especially during fetal development and in the first years of life, when the organs, lungs, and brain are developing (SILVA et al., 2021).

The increase in temperature and humidity can favor the formation of ozone in the lower atmosphere, a contaminant that can cause irritation to the eyes, nose, and throat, as well as impair lung function (LIANG et al., 2015). Chronic exposure to air pollutants, in addition to the addition of respiratory diseases, may increase the risk of cardiovascular, neurological, and metabolic diseases (CHAO et al., 2021). According to a recent study by Niu et al. (2019), there was a clear association between prolonged exposure to ozone and an increased risk of mortality from cardiovascular disease, especially ischemic heart disease. The study also found that people 65 and older may be more vulnerable to cardiovascular mortality due to environmental ozone pollution than those under 65. Age has been identified as one of the most common demographic characteristics that increase susceptibility to short-term exposure to ozone, although there is no evidence for this observation in studies of long-term exposure. Subgroup analyses conducted in the study consistently showed significant associations between prolonged ozone exposure and elevated mortality risks due to general cardiovascular disease, ischemia, heart disease, and stroke.

A recent study conducted in Denmark used a national administrative cohort and assessed exposure to air contaminants over time to examine the impact of air pollution on mortality from diseases unrelated to heart disease and lung cancer. Prolonged exposure to atmospheric particulate matter, nitrogen dioxide, and black carbon have been associated with a significant increase in the risk of mortality from diabetes, dementia, and psychiatric disorders, as well as mortality from natural causes, cardiovascular disease, kidney disease, and lung cancer (LASSEN et al., 2022).

7 OZONE DEPLETION AND DELETERIOUS EFFECTS OF ULTRAVIOLET (UV) RAYS ON HUMANS

The amount of ultraviolet radiation reaching the Earth's surface is directly influenced by the concentration of ozone in the atmosphere. Even small variations in this layer can pose a major health hazard, as demonstrated by a recent study that pointed to a 2.7% increase in the incidence of non-melanoma skin cancers for every 1% reduction in atmospheric ozone (JUCHEM et al., 1998).

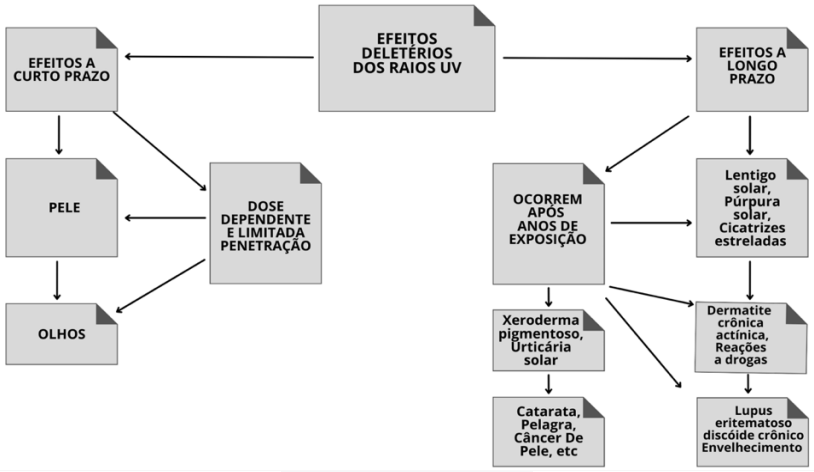
For this reason, UV radiation is a complex subject with both beneficial and detrimental effects on health. On the one hand, sun exposure is important for stimulating the production of vitamin D3,

which is essential for bone metabolism and the functioning of the immune system. In addition, phototherapy, which involves the patient's-controlled exposure to UV radiation, is often used in conjunction with medications to treat dermatological conditions such as psoriasis and vitiligo. On the other hand, prolonged exposure to UV radiation has as its main effect the alteration of DNA, which can lead to mutations in pyrimidine dimers and increase the risk of non-melanoma skin cancers, such as basal cell carcinoma and squamous cell carcinoma. In addition, UVA radiation, which has longer wavelengths and less energy than UVB, can penetrate deep into the dermis and aggravate skin problems like lupus erythematosus and polymorphous sunlight rash. Prolonged exposure to the sun can also cause problems such as wrinkles, roughness, dryness, irregular pigmentation, immunosuppression, and benign, premalignant, or malignant lesions on the skin. What's more, prolonged exposure to the sun without adequate protection can cause eye damage such as cataracts, macular degeneration, photo conjunctivitis, and cataracts (BALOGH et al., 2011; MCKENZIE and LILEY 2018).

There are about 40 types of diseases that can be originated or aggravated by sun exposure, including genetic diseases such as xeroderma pigmentosum and albinism, metabolic disorders such as porphyrias, diseases induced by phototoxic or photo allergenic drugs, photo immunological diseases, degenerative or neoplastic diseases, as well as other pathological conditions, such as solar urticaria and discoid lupus erythematosus (JUCHEM et al., 1998).

When it comes to the health effects of ultraviolet radiation (UVR), we can distinguish two groups: the acute, which manifests immediately after exposure, and the long-term effects, which accumulate over time and increase the risk of health problems. The former is influenced by the amount of radiation to which the person has been exposed and usually affects only the skin and eyes. Late effects can come after years of exposure to UVR, whether from natural or artificial sources and include loss of skin elasticity, which can lead to premature aging, as well as increased risk of developing certain types of cataracts. It is not known for sure what is the relationship between the amount of radiation and the occurrence of these late effects, emphasizing that the main risk associated with UVR exposure is the development of skin cancer (JUCHEM et al., 1998). To visualize the distinction between the acute and late effects of UVR on health, presented in Figure 2 shows that the acute effects of UVR mainly affect the skin and eyes, while the late effects can lead to premature aging of the skin, increased risk of cataracts and development of cancer. of skin.

Figure 2 - Flowchart representing the harmful health effects of UV rays, including the acute and late effects of ultraviolet radiation.



(Source: Self-authored)

8 ENDEMIC AND INFECTIOUS DISEASES ASSOCIATED WITH ECOLOGICAL CHANGES CAUSED BY CLIMATE CHANGE

Climate change is a global concern as it has the potential to affect public health around the world. When discussing climate change associated with the global greenhouse effect, Haines (1992) stated that several parasitic diseases currently limited to tropical regions, such as malaria, trypanosomiasis, leishmaniasis, filariasis, amebiasis, onchocerciasis, schistosomiasis, and various verminous, are related to temperature and could, in theory, be affected by climate change, as shown in Table 1.

The increase in temperature and humidity favors the proliferation of mosquitoes that transmit malaria, dengue, and yellow fever in addition to other viral diseases transmitted by arthropods, as well as bubonic plague, dysentery, and other diarrheal diseases, which can lead to an increase in the incidence of these pathologies in areas that were previously unaffected (EPSTEIN et al., 1998; Mendonca, 2003; ROGERS & RANDOLPH, 2000). Changes in rainfall, temperature, and water quality patterns can also affect and increase the risk of infectious diseases such as cholera, leptospirosis, and hepatitis A, as well as the proliferation of bacteria and viruses in places without adequate sanitation. (United Nations Environment Programme, 2016; FREITAS, 2018). Some studies also suggest that increasing temperature may increase the prevalence of antibiotic-resistant bacteria in aquatic environments (BAKER-AUSTIN et al., 2013). Therefore, it is important to understand how climatic factors impact biological processes, such as the life cycle of pathogenic organisms and disease vectors.

These aspects have been widely studied in the area of ecology to assess the risks of climate variability in the transmission of infectious diseases. The transmission of diseases can occur between humans, known as anthroponoses, or between animals and humans, called zoonoses. In both cases,

transmission can occur directly or through vectors, which highlights the importance of effective preventive measures to combat the spread of diseases (PATZ et al., 2003).

Recently, the COVID-19 pandemic has brought renewed attention to the relationship between human health and planetary health. Scientific studies have argued that the pandemic is a symptom of the Anthropocene era, a period when human activities are causing significant changes on the planet (HRIBAR, 2020). The scientific literature has provided a critical review of the relationship between coronavirus and the environment, including discussions of the environmental implications of the pandemic and government and civil society responses to the crisis (STEFFEN et al., 2020). Some studies have compared global responses to the pandemic and climate change, arguing that both crises require global and coordinated responses (FOLKE et al., 2020).

Table 1 - Relationship between infectious and parasitic diseases and climatic and environmental factors

SICKNESS	TRANSMISSION	ENVIRONMENTAL CLIMATIC FACTORS
CHIKUNGUNYA	Bite of an infected mosquito of the genus Aedes	Temperature and precipitation affect the activity of the vector mosquito and therefore the transmission of the disease.
DENGUE FEVER	Bite of an infected mosquito of the genus Aedes.	Temperature and precipitation affect the activity of the vector mosquito and therefore the transmission of the disease.
ZIKA	Bite of an infected mosquito of the genus Aedes.	Temperature and precipitation affect the activity of the vector mosquito and therefore the transmission of the disease.
CHOLERA	Ingestion of water or food contaminated with the bacterium Vibrio cholerae.	Water temperature and salinity affect the survival and spread of Vibrio cholerae bacteria in aquatic environments.
BLACK VOMIT	Bite of an infected mosquito of the genus Aedes or Haemagogus.	Temperature and precipitation affect the geographic distribution and seasonality of transmitting mosquitoes.
VISCERAL LEISHMANIASIS	Bite of sandfly mosquitos infected with the Leishmania parasite.	Temperature and humidity affect the geographic distribution and activity of transmitting mosquitoes.
MALARIA	Bite of an infected mosquito of the genus Anopheles.	Climate change can affect the geographic distribution of transmitting mosquitoes and the seasonality and intensity of transmission.
COVID-19	Inhalation of respiratory droplets expelled by infected people during speech, coughing, or sneezing.	Environmental conditions such as humidity and temperature can influence the spread of the virus.

Source: Own authorship

The COVID-19 pandemic can provide valuable lessons on how to tackle climate change, as social distancing measures and reduced economic activity have led to a significant decrease in greenhouse gas emissions (Le Quéré et al., 2020). However, it also presents opportunities for transformational change towards sustainability. The crisis has driven innovations in technology and

changes in individual behaviors, such as the adoption of remote work practices and sustainable transportation (Lelieveld et al., 2020). Responses to the pandemic also highlight the importance of international cooperation and evidence-based science to address global crises (Venter et al., 2020).

9 SOCIO-ENVIRONMENTAL VULNERABILITY

Harmful ultraviolet radiation, which reaches the earth's surface, harms flora and fauna, reducing the ability of plants to photosynthesize and grow. This can affect food production and biodiversity. In addition, the depletion of the ozone layer can contribute to climate change, leading to extreme weather events such as droughts, floods, and more intense storms (IPCC, 2021).

Socio-environmental vulnerability resulting from the depletion of the ozone layer is more common in developing countries and vulnerable populations, such as indigenous peoples and coastal communities. Such populations often depend on nature for their livelihoods and have limited access to the resources needed to protect themselves from harmful ultraviolet radiation (UNEP, 2022; WHO, 2016).

It is important to highlight that the consequences of ozone depletion and climate change are uneven and affect the poorest and most marginalized communities most intensely. Socio-environmental vulnerability is an important concern and one of the main health problems related to global warming is malnutrition (WATTS et al., 2018). Changes in weather patterns can affect agricultural production, decreasing food supply and driving up prices. This can lead to a decrease in food intake, which can lead to a few health problems, such as malnutrition and anemia (BOSCOLO, 2019). In addition, it is necessary to consider that the most vulnerable groups, such as children, the elderly, low-income people, and rural communities, may be more exposed to the negative effects of UV exposure. These groups may also have less access to adequate health care to treat the effects of UV exposure (Adger et al., 2019; Lelieveld et al., 2020).

According to the World Health Organization (WHO, 2020), considering exclusively the health impacts and assuming constant economic growth, it is estimated that climate change will result in about 250,000 additional deaths per year between 2030 and 2050. Of these deaths, 38,000 are expected to occur among heat-exposed older adults and 95,000 are caused by child malnutrition.

Another relevant issue is mental health. Global warming can trigger or aggravate problems such as stress, anxiety, and depression. The loss of loved ones, the destruction of homes, and the sudden change in weather patterns can have a major psychological impact on people (HANSEN, 2015).

In addition, the COVID-19 pandemic has also exposed the social and economic inequalities that are exacerbated by environmental degradation and the need to address planetary and socio-environmental health issues more broadly and holistically. Vulnerable populations, including low-

income communities and ethnic minorities, have been disproportionately affected by the pandemic, due to factors such as lack of access to health care and overcrowded housing (EBI et al., 2020b). In addition, these same communities are more exposed to environmental risks, such as air and water pollution, due to the location of their homes near industrial areas (Jat et al., 2020b).

According to Ojima and Hogan (2008a), urban areas are more vulnerable to climate change due to the great social contrasts and the presence of a large portion of the population living and acting in direct contact with the environment. In this sense, it is necessary to develop specific public policies for these areas (Ojima and Hogan, 2008b).

10 MEASURES TO ENSURE PLANETARY HEALTH

From the analysis carried out, the citation of Whitmee et al. (2015) points to the need for coordinated action by different sectors of society to address global health and environmental crises. This claim is corroborated by other sources, which highlight the importance of collaboration and cooperation to achieve effective and sustainable solutions to the problems we currently face.

In addition, the quote also highlights the need to consider the interconnectedness between global crises. In this sense, Lelieveld et al. (2020) point to the importance of adopting remote work practices and sustainable transportation to reduce the environmental impact of carbon and contribute to the mitigation of climate change. These practices can also contribute to climate change adaptation by reducing exposure to extreme events such as heat waves.

The 2018 Intergovernmental Panel on Climate Change (IPCC) report, for example, underscores that international cooperation is essential to address the impacts of climate change and that action must be integrated across multiple sectors, including governments, businesses, and civil society. In addition, it highlights the importance of evidence-based science to guide policies and solutions adopted.

Based on the literature review conducted, authors Lelieveld et al. (2020) and Whitmee et al. (2015) emphasize the interconnection between human health and planetary health. This has been well evidenced in the COVID-19 pandemic. Both advocate an integrated approach that takes both aspects into account, providing a critical view of the relationship between coronavirus and the environment, pointing out the associated impacts on the environment of a said health crisis, and the opportunities for transformational changes towards sustainability. The global health crisis has forced many companies and organizations to adopt remote working practices and rethink their transportation strategies, which can have a positive impact in terms of greenhouse gas emissions and air quality. However, it is important to remember that these changes should not be seen as permanent solutions to environmental problems, but rather as opportunities to transition to a more sustainable model, driving innovations in technology and changes in individual behaviors.

For the authors Lelieveld et al. (2020), it is imperative to reduce the emission of gases that affect the ozone layer and expand food and agricultural systems that address market failures. A preventive strategy is crucial in the approach to health, which should include complementing curative, biomedical, and molecular medicine with a focus on addressing the environmental and social roots of health problems (Whitmee et al., 2015). It is also important to develop health systems that are better prepared to face challenges, integrate health and environmental responsibility, particularly at the primary care level, and incorporate planetary health into the allocation of resources in the medical field.

Finally, the same authors highlight the importance of public policies that consider the interconnection between global crises and promote solutions in multiple sectors. This integrated approach is critical to addressing the complex challenges we face today and to ensure lasting and sustainable solutions. In line with the cited authors, a joint and coordinated effort by governments, international organizations, the private sector, and civil society is needed to address global health and environmental crises, based on scientific evidence, to develop policies and strategies that address global challenges in a comprehensive and unified manner.

Given this, it is essential to adopt government measures that consider the interdependence between human health and planetary health, to promote sustainability and the preservation of the environment for future generations.

In summary, there must be a greater awareness of the importance of the health of the planet for the health of the human being. To achieve a more sustainable and healthy future, there needs to be a change in the paradigm of physical and mental balance condition, with a more preventive and holistic approach. This includes the development of more adaptable medical services, integrating health and care for the environment. In addition, it is essential to complement curative, biomedical, and molecular therapeutics with precision medicine, which focuses on addressing the environmental and social roots of diseases. Research in this field is advancing rapidly and offers great hope for improving population health (Whitmee et al., 2015).

As stated by the authors, it is necessary to integrate environmental health into the budgetary processes dedicated to health, being considered a priority to ensure a healthier and more sustainable future for the current and new generations.

ACKNOWLEDGMENT

The authors thank the scholarship of FACEPE (Foundation for the Support of Science and Technology of Pernambuco) Process No. IBPG-1171-3.06/22 of Felipe Casa Nova Furtado; the CAPES Scholarship (Coordination for the Improvement of Higher Education Personnel) Process No. 88887

83861/2023-00 to Fátima de Cássia de Athayde Borille; the UNICAP (Catholic University of Pernambuco) scholarship and UPE release, Andrea the Melo and the CNPq Grant (National Council for Scientific and Technological Development) Process No. 312241/2022-4, Galba M. Campos-Takaki and the Catholic University of Pernambuco for the availability of academic and laboratory spaces.

REFERENCES

Adger, w. Neil et al. Health and climate change. Lancet, v. 373, n. 9676, p. 2008-2018, 2009.

Barbosa Lima, leandro josé et al. Poluição atmosférica e gases de efeito estufa no brasil. In: anais do xi congresso internacional de ciência, tecnologia e desenvolvimento (xi cicted). Editora do cicted. Doi: 10.29327/xicicted2022.563736. 2022

Baird, c. Química ambiental. 2ª edição, bookman, porto alegre, 2002.

Baker-austin, c. Et al emerging vibrio risk at high latitudes in response to ocean warming. Nature climate change, v. 3, n.1, p. 73-77, 2013.

Balogh, tatiana santana, et al. Proteção à radiação ultravioleta: recursos disponíveis na atualidade em fotoproteção. *Anais brasileiros de dermatologia*, v. 86, n· 4, p. 732–742, 2011. Https://doi.org/10.1590/s0365-05962011000400016.

Besancenot, jp. Aquecimento global e saúde: uma perspectiva geográfica – notas introdutórias. Interface (botucatu), v. 5, p. 55-66, 2001.

Boscolo, juliana frizzero. Mudanças climáticas globais e impactos na saúde: uma revisão integrativa da literatura. Saúde debate, v. 43, n. 121, p. 104-120, 2019.

Chao, l., lu, m., an, z. *Et al.* Short-term effect of no2 on outpatient visits for dermatologic diseases in xinxiang, china: a time-series study. *Environ geochem health* v. 43, p. 1–11, 2021. Https://doi.org/10.1007/s10653-021-00831-3.

Epstein, p. R. Et al. Biological and physical signs of climate change: focus on mosquito-borne diseases. Bulletin of the american meteorological society, v. 79, n. 3, p. 409-417, 1998.

Ebi, k. L. Et al. Emerging infectious diseases and the environment: a one health perspective. Environment international, v. 141, p. 105764, 2020a.

Ebi, kristie l. Et al. Climate change and health equity: time to act. The lancet, v. 395, n. 10231, p. 1244-1246, 2020b.

Epstein, p. R. Et al. Biological and physical signs of climate change: focus on mosquito-borne diseases. Bulletin of the american meteorological society, v. 79, n. 3, p. 409-417, 1998.

Forster, p. Et al mudanças nos constituintes atmosféricos e no forçamento radiativo. In: solomon, s., ed., mudança climática 2007: a base da ciência física. Contribuição do grupo de trabalho i para o quarto relatório de avaliação do painel intergovernamental sobre mudanças climáticas, cambridge university press, cambridge, 2007.

Freitas, c. M. Mudanças climáticas e saúde: impactos, adaptação e vulnerabilidade, blucher, 2018.

Folke, c. Et al. Adaptive governance of social-ecological systems through the covid-19 pandemic. Global sustainability, v. 3, p. 1-6, 2020.

Gao, j. Et al. The health effects of ambient pm2.5 and potential mechanisms. Ecotoxicology and environmental safety, v. 145, p. 395-408, 2017.

Haines, a.; ebi, k. Climate change and health: the challenges ahead. Jama, v. 321, n. 5, p. 437-438, 2019.

Haines, a. Et al. Public health benefits of strategies to reduce greenhouse-gas emissions: overview and implications for policy makers. Lancet, v. 384, n. 9959, p. 2104-2114, 2014.

Hansen, james et al. Perception of climate change. Proceedings of the national. Academy of sciences, v. 112, n. 43, p. 13194-13195, 2015.

Hribar, c. Covid-19 and the anthropocene: navigating social and environmental health in the new planetary epoch. Health & place, v. 64, n. 102378. 2020.

Horton, r. Et al. Da saúde pública à saúde planetária: um manifesto. The lancet, v. 383. N. 9920, p. 847. 2014

Horton, r. Et al. Da saúde pública à saúde planetária: um manifesto. The lancet, v. 383, n.9920, p. 847, 2014.

Intergovernmental panel on climate change. Climate change 2021: the physical science basis. Contribution of working group i to the sixth assessment report of the intergovernmental panel on climate change. Cambridge university press; 2021. Available from: https://www.ipcc.ch/report/ar6/wg1/

Ipcc (2006). Diretrizes para inventários nacionais de gases de efeito estufa. Disponível em: http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html. Acesso em: 21 de abril de 2023.

Ipcc. (2018). Aquecimento global de 1,5°c: um relatório especial do ipcc sobre os impactos do aquecimento global de 1,5°c acima dos níveis pré-industriais e as vias globais de emissão de gases de efeito estufa relacionadas, no contexto do fortalecimento da economia global. Disponível em: https://www.ipcc.ch/sr15/. Acesso em: 02 maio 2023.

Jat, prahlad k. Et al. Exposure to environmental pollutants and covid-19 and suspected role of air pollution: a review. Chemosphere, v. 263, p. 127978, 2020.

Jat, prahlad k. Et al. Assessing exposure and health consequences of chemicals in drinking water: current state of knowledge and research needs. Environmental health perspectives, v. 128, n. 8, p. 085001, 2020.

Joaquim et al. Sustainable waste management as a climate change mitigation stategy. Journal of cleaner production, v. 202, p. 939-947, 2018.

Juchem pp. Et al. Riscos à saúde da radiação ultravioleta. Rev. Bras. Cir. Plást., v. 13, n. 2, p. 31-60, 1998.

Kirschbaum, daniel b. Et al. The effects of stratospheric ozone depletion and climate change on human health. Environment international, v. 108, p. 155-166, 2017.

Lassen, c. F. Et al. Long-term exposure to air pollution and mortality in a danish nationwide administrative cohort study: beyond mortality from
Cardiopulmonary disease and lung cancer. Environment international, v. 159, n.107241. Https://doi.org/10.1016/j.envint.2022.107241. 2022.

Lelieveld, jos et al. cardiovascular disease burden from ambient air pollution in europe reassessed using novel hazard ratio functions. European heart journal, v. 40, n. 20, p. 1590-1596, 2019. Doi: https://doi.org/10.1093/eurheartj/ehz135.

Le quiré, c. Et al. Temporary reduction in daily global co2 emissions during the covid-19 forced confinement. Nature climate change, londres, v. 10, n. 7, p. 647-653, jul. 2020.

Liang, x.-z. Et al. Sensitivity of surface ozone to the meteorological parameters in the beijing–tianjin–hebei region, china. Atmospheric pollution research, v. 6, n. 4, p. 672-680, 2015.

Lima, l. J. B. Et al. (2022). Poluição atmosférica e gases de efeito estufa no brasil. In anais do xi congresso internacional de ciência, tecnologia e desenvolvimento: xi cicted 2022. Https://doi.org/10.29327/xicicted2022.563736 disponível em: <https//www.even3.com.br/anais/xicicted2022/563736-poluicao-atmosferica-e-gases-de-efeito-estufa-no-brasil>. Acesso em: 01/05/2023

Lovett, p. J. Et al. Knowledge-based engineering for smes - a methodology. Journal of materials processing technology, v. 107, n. 1- 3, p.384-389, 2000.

Lovett, richard. Climate change and biodiversity. Nature, v. 527, n. 7576, p. S2-s3, 2019.

Lui, cw. Et al. A importância da educação ambiental para consciência ambiental pública: uma exploração de estudantes universitários chineses. Journal of cleaner production, v.208, p. 162-173, 2019.

Madronich, s. Radiação uv na atmosfera natural e perturbada. Em: tevini, m., ed., efeitos ambientais da radiação uv (ultravioleta), lewis, boca raton, p. 17-69, 1993.

Mckenzie r, liley b. Ultraviolet radiation and health: a review of recent research. Iarc monogr eval carcinog risks hum. V. 114, p. 1-324. 2018.

Mendonça, f. Aquecimento global e saúde: uma perspectiva geográfica - notas introdutórias. Terra livre são paulo, v. 19, n. 1, p. 205-221, 2003.

Mendonça, gustavo henrique. Camada de ozônio. Brasil escola. Disponível em: https://brasiescola.uol.com.br/geografia/camada-de-ozonio.htm. Acesso em 30 de abril de 2023.

Ministério da saúde. Mudanças globais e desenvolvimento: importância para a saúde-informe epidemiológico do sus. 2018.

Molina, mario et al pia estratosférica para clorofluorcarbonos; destruição catalisada por átomos de cloro do ozônio. Nature, v.249, p.810-812, 1974.

Niu, y. Et al. Long-term exposure to ozone and cardiovascular mortality in china: a nationwide cohort study. The lancet planetary health, v. 3, n. 11, p. 492-501, 2019.

Ojima, d. S.et al. Vulnerability of urban social-environmental systems to climate change: a conceptual framework. Climate change and social justice. Springer, dordrecht. P. 121-135. 2008.
Ojima, d. S. Et al. Climate change and vulnerable urban systems: concepts and research issues. Environment and planning c: government and policy, v. 26, n. 2, p. 191-204, 2008.

Patz, j. A. Et al. Impact of regional climate change on human health. Nature, v. 438, n. 7066, p. 310-317, 2005.

Patz, j.a. Et al. Unhealthy landscapes: policy recommendations on land use change and infectious disease emergence. Environmental health perspectives, v. 112, n.10, p. 1092-1098, 2004.

Petit, j. R. Et al. Clima e história atmosférica dos últimos 420.000 anos do núcleo de gelo vostok, antártida. Nature, v. 399. P. 429-436, 1999.

Planetary health alliance. Disponível em: https://www.planetaryhealthalliance.org/home-page. Acessado em: 30 de abril de 2023.

Raposo, a. Et al. Revisão bibliográfica dos efeitos da poluição do ar sobre a saúde humana e uma breve análise crítica da atual legislação brasileira sobre os padrões de qualidade do ar (conama 491/2018). Cadernos do leste, [s. L.], v. 21, n. 21, 2021. Doi: 10.29327/248949.21.21-1. Disponível em: https://periodicos.ufmg.br/index.php/caderleste/article/view/35677. Acesso em: 1 maio. 2023.

Rehman, f. Et al. (2019). Impacto das mudanças climáticas na saúde pública: uma revisão sistemática. Jornal europeu de saúde pública e ambiental, v. 3, n. 1, p. 1-11, 2019.

Rogers, d. J. Etv al. The global spread of malaria in a future, warmer world. Science, v. 289, n. 5485, p. 1763-1766, 2000.

Silva, m. T. Et al. Proteção à radiação ultravioleta: recursos disponíveis na atualidade em fotoproteção. Journal of health & biological sciences, v. 7, n. 4, p. 344-355, 2019.

Silva, j. M. S. Et al. Climate change and the potential spread of vector-borne diseases: using gis to predict areas suitable for tick and mosquito species in the state of rio de janeiro, brazil. Geospatial health, v. 15, n. 2, p. 294-302, 2020.

Silva, j. A. Et al. Revisão bibliográfica dos efeitos da poluição do ar sobre a saúde humana: breve análise crítica da atual legislação brasileira sobre os padrões de qualidade do ar. Cadernos do leste, v. 21, n. 21, issn 1679-5806, doi: 10.29327/248949.21.21-1, 2021. Disponível em: https://periodicos.ufmg.br/index.php/caderleste/article/view/35677. Acesso em: 1 maio. 2023.

Souza, l. R. De. Et al. Impactos das mudanças climáticas na saúde: uma revisão sistemática da literatura. Revista brasileira de epidemiologia. V. 24, n. 210042, 2021.

Steffen, w. Et al. Planetary health: from the wellspring of holistic medicine-to a blueprint for the future. The lancet planetary health, [s.l.], v. 4, n. 5, p. 197-202, 2020.

United nations environment programme. Climate change and human health. Geneva: world health organization. 2016

United nations environment programme. Scientific assessment of ozone depletion: 2022. Geneva: united nations environment programme. 2022. Disponível em: https://ozone.unep.org/scientific-assessment-ozone-depletion-2022. Acesso em 01 de abril de 2023.

Venter, z. S. Et al. Covid-19 lockdowns cause global air pollution declines with implications for public health risk. Medrxiv. 2020.

Watts, nick et al. The 2018 report of the lancet countdown on health and climate change: shaping the health of nations for centuries to come. The lancet, v. 392, n. 10163, p. 2479-2514, 2018.

Whitmee, sarah, et al. Safeguarding human health in the anthropocene epoch: report of the rockefeller foundation–lancet commission on planetary health. The lancet, v. 386, n. 10007, p. 1973–2028, 2015. Https://doi.org/10.1016/s0140-6736(15)60901-1.

Who - world health organization. Climate change and health. 2020. Disponível em: https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health. Acesso em: 01 maio 2023.