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EDITORIAL

# Pandemics, climate change, and the eye

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## Introduction

Global climate change is primarily a sequel of human's impact on the planet. More than 150 years ago, Marsh recognized and praised the benefits of the interaction between man and nature. However, he was also the first to severely criticize their relationship, suggesting that further abuse by humans could result in the extinction of the species. This exploitation of Earth's resources led Nobel Prize laureate Paul Crutzen to coin a new term: "Anthropocene" or "The Age of Man" [1].

Humanity's disruptive behavior could have started with the Industrial Revolution in the mid-eighteenth century and has continued for the past three centuries. In 1997, Vitousek et al. estimated that 39–50% of the world's land surface has been transformed or degraded by human activity [2]. Furthermore, a persistent increase in levels of fossil-fuels has released abundant greenhouse gases (GHG), contributing to a global crisis of air pollution. The energy imbalance as a result of pollution induces accumulation of heat with the subsequent warming of the planet.

In fact, the Intergovernmental Panel on Climate Change (IPCC) calculated that the Earth will warm by 1.5 °C during this century [3], causing a massive climate-induced change in the migration pattern of wildlife animals, bringing them into greater contact with humans. Currently, the COVID-19 pandemic has exposed our vulnerability. In a couple of weeks, it brought normal life to an almost complete halt.

The primary aim of this review is to describe the impact of environment on the spread of zoonoses and how climate can influence the development of eye diseases. Some of the possible outcomes from COVID-19 will also be delineated, respectively.

## Pandemics and climate change

The climate system is interactive and evolves in time under the influence of several factors:

### Little Ice Age

Little Ice Age is a period between 1300 and 1850 that is known for its colder temperatures, with an average drop of 0.5 °C. Although most of the cooling may have been caused by a decrease in sunspot activity or a surge in volcanic eruptions, evidence suggests that it could be to some extent man-made [4]. A vicious cycle had started: Several plagues had claimed the lives of millions, leaving extensive land to reforest, lowering the levels of carbon dioxide ($CO_2$) with a subsequent decrease in temperature. On a global scale, extreme climate with freezing conditions increased harvest failures, famine, and malnutrition, resulting in prominent outbreaks of new and old epidemics [5].

### Global warming

Since 1751 the world has emitted—approximately—over 1.5 trillion tons of $CO_2$ [6], contributing to the increment of global temperatures over 1 °C, with unprecedented changes since the mid-twentieth century. Prosperity and advances in technology, the hallmarks of the second half of the century, are primary drivers of $CO_2$ emissions. Therefore, the sustained human release of greenhouse gases is the main reason attributed to the rise in temperatures [7]. To address climate change, the United Nations (UN) established the *Paris Agreement*, setting a target, limiting average warming to 2 °C, urging the world to urgently reduce emissions.

Regarding health effects, several studies have estimated that global warming will induce deadly hurricanes by

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intensified rainfall and stronger winds. Furthermore, rising sea levels will acidify the ocean, and drought and fires will worsen pollution. Such conditions have a lasting impact on sea temperatures and air quality, direly affecting ecosystems, and leading to waterborne and airborne diseases [8], aggravating chronic conditions and ultimately anticipating higher rates of premature death. An unstable climate may also threaten pathogen hosts, inducing relocation of microorganisms and hosts [3]. These shifts have been suggested as the reason for emerging infectious diseases [9] (Fig. 1).

In December of 2019, Dr. Li Wenliang, a Chinese ophthalmologist, warned the world about the potential danger of a cluster of pneumonia cases in Wuhan, China [10]. The outbreak was later traced back to the seafood and wet animal wholesale market in Wuhan. Moreover, samples from the live animal section of the market were positive for the virus. A novel coronavirus was identified as the etiologic agent of this deadly disease. COVID-19 rapidly proved to have human-to-human transmission spreading through the world at a fast pace, jeopardizing the modern world.

As of September 4, 2020, COVID-19 has infected more than 6 million people in the USA, killing over 190,000 [11]. However, these statistics might not be entirely accurate. Several factors prevented the containment of the epidemic and enabled exponential growth of cases, revealing our country’s flaws in the management of an outbreak of this magnitude. History has shown that the worst epidemics ravaged nearly entire civilizations, but the impact of an epidemic goes beyond the death toll, involving the global economic collapse and climate change.

## COVID-19 possible outcomes

We can postulate that the aftermath of closing borders, bars, and schools, in addition to travel bans and shelter in place orders around the world, has brought some benefits to the planet. At least momentarily, Mother Earth seems to be healing.

### Benefit: reduction of air pollutants

NASA (National Aeronautics and Space Administration) and ESA (European Space Agency) have announced that China and Italy are showing a cleaner air amid the quarantine. The dramatic drop-off of Nitrogen dioxide ($NO_2$) pollutions have lifted the fog of densely populated cities around the world, in particular, Los Angeles and Mumbai. In a similar manner, satellites from the Copernicus Atmosphere Monitoring Service measured a decline of 20–30% in surface $PM_{2.5}$ over large parts of China in February 2020 [12]. At large, carbon emissions have sharply fallen across continents. Similarly, the United States Energy Information Administration has reported

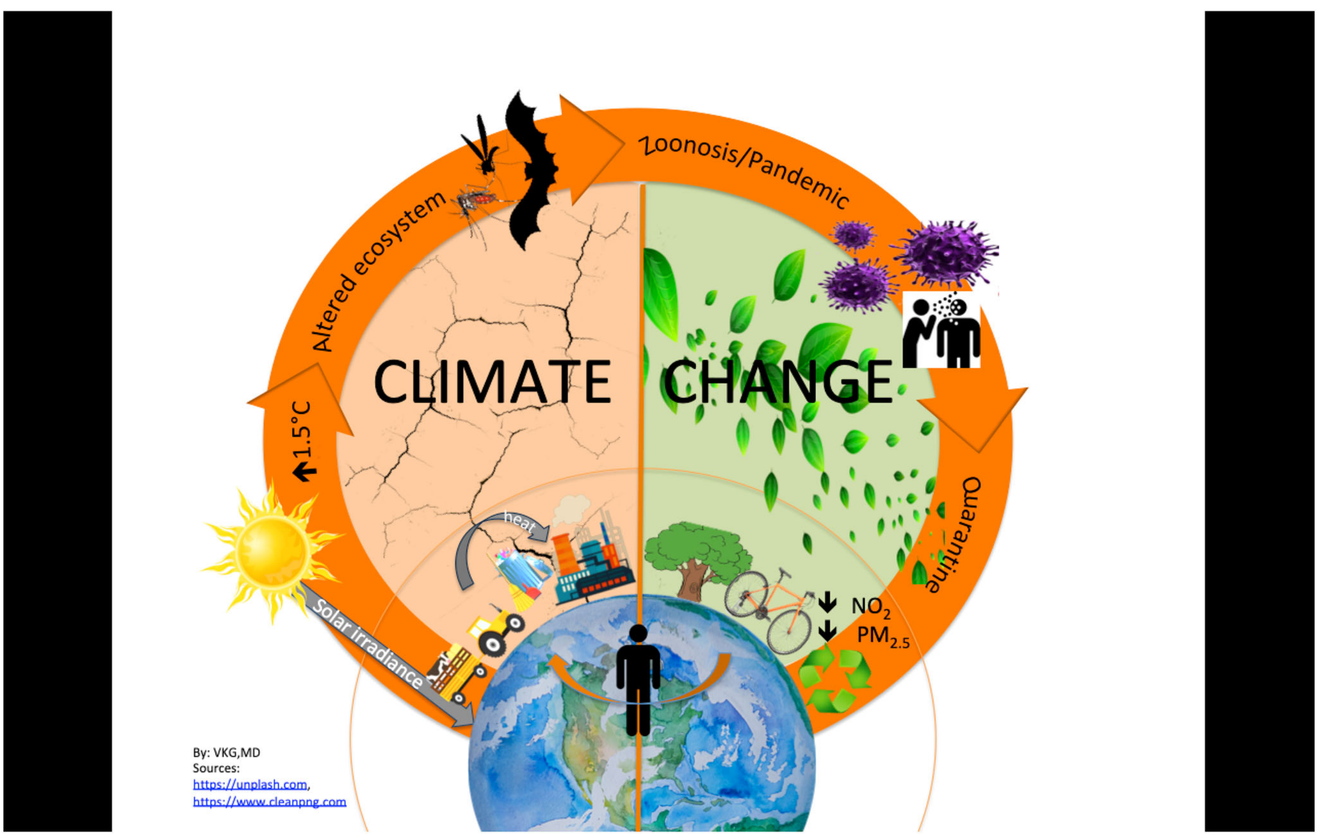


**Fig. 1** Graphic depicting the cycle between climate change and zoonoses

a predicted 11.5% reduction in emissions during 2020, as a ramification of the pandemic [13].

### Disadvantage: increase of medical and hazardous waste

A few months ago, the head of the UN Environment Programme (UNEP) cautioned the world: "COVID-19 is not a silver lining for the climate" [14]. Despite the favorable changes in carbon footprint, the mitigation might be temporary. Patients and healthcare workers are now producing significant medical and hazardous waste. Of more concern, Americans have been hoarding supplies such as masks, gloves, and cleaning materials since the beginning of the epidemic. The proper disposal of these provisions is questionable.

In Wuhan, the first epicenter of the pandemic, hospitals' daily waste reached 240 metric tons, a sixfold increment compared with the amount before the epidemic started [15]. Thus far, hospitals in the USA have not been burdened this way; however, it is uncertain how much additional waste will be produced as a result of the outbreak.

## Climate change and ophthalmology

The intriguing chain reaction of global warming in ocular health is ominous. The spectrum of eye diseases can be categorized by exposure to specific environmental factors, and their severity appears to be directly linked to the duration of that exposure.

### Ozone depletion and ultraviolet radiation

Most atmospheric ozone is concentrated in the stratosphere. With a program launched in 1970, NASA has continuously monitored the status of the ozone layer, partaking in the discovery of their depletion in the early 1980s [16]. The main function of the ozone layer is to protect life on Earth by absorbing harmful ultraviolet light (UV). Among the radiation reaching Earth's surface, 10% belongs to the medium-wavelength band (280–315 nm) or UVB; and the long-wavelength band (315–390 nm) or UVA accounts for the remaining 90%. The eye is one of the two organs susceptible to solar irradiance; hence radiation from direct sunlight and sky scattering and reflection from clouds, ground, and other surfaces have deleterious consequences [16]; and strong epidemiological evidence associates them with the development of *photochemical damage to ocular tissues* [17].

The photochemical injury is predominantly due to *photo-oxidative damage* where the creation of reactive oxygen species plays a central role. The length of exposure, the wavelength of UV rays, and tissue irradiance determine the severity of the lesion:

Acute phototoxic lesions are seen on the *ocular surface* as photokeratitis and conjunctivitis and the *retina* as solar retinopathy.

Chronic exposure to solar energy may induce damage to the ***eyelids*****:** keratoacanthoma, actinic keratosis, and neoplasias; ***conjunctiva*****:** pterygium, pinguecula, metaplasia, or carcinoma of the conjunctiva; ***cornea****:* climatic droplet keratopathy (Labrador), keratoconus, endothelial cell damage, and dry eye; ***lens****:* cataract and early presbyopia; and ***trabecular meshwork:*** glaucoma. Regarding the ***retina*****,** studies have failed to conclusively support the relationship of UV light and disorders such as choroidal melanoma and macular degeneration [16–20].

Thus, exogenous agents may contribute to chemical injury by acting as *photosensitizers* [17]. These components include tetracyclines, chloroquine, nonsteroidal anti-inflammatory drugs, and psoralen, among others, reaching the ocular tissues directly or indirectly via the circulation.

### Thermal damage

High ambient temperature attributable to global warming may influence thermal damage in ocular structures. Bacterial keratitis caused by *Staphylococcus aureus* and *Pseudomonas* have been found to be more prevalent in warmer climates [21]. Fungal keratitis is more common in certain geographic areas with hotter weather. A hot environment may then potentially worsen the burden of trachoma and may trigger the formation of cataracts and the occurrence of central retinal artery occlusion (CRAO) [18, 22, 23].

### Air pollution

Air pollution is a mixture of harmful substances in the air we breathe. Besides of pollutant gases, airborne suspensions "particulate matter" (PM) are particularly detrimental for human health. Several studies have shown evidence that $PM_{2.5}$ alters the microvascular endothelium-dependent dilation. Moreover, Adar et al. demonstrated significantly narrower retinal arteriolar diameters in people living in areas of elevated pollution [24], and Cheng et al. established a possible link between pollutants and CRAO [24]. A large report from the UK also found a considerable association between higher $PM_{2.5}$ exposure and the risk of ganglion cell loss and glaucoma [25].

The USA (US) currently ranks first in healthcare spending among the developed nations of the world. It is widely recognized that waste in the healthcare system contributes to the prominent cost of medical care. Several strategies have been evaluated to assist with cost reduction, estimating that the best approach was the minimization of waste, with future savings that could represent > 20% of the total health care expense

[26]. Ophthalmology, as a surgical specialty, plays a part in generating one third of all hospital-regulated medical waste [27].

Likewise, healthcare services are responsible for nearly 10% of the USA's carbon footprint. A study compared the generation of greenhouse gases and expenditures of a single cataract surgery between the Aravind Eye Care System from India and the UK. The results were eye-opening: an eco-friendly resource with comparable-to-better patient outcomes and substantial less spending. The same study reported that up to 60% of drugs used during elective phacoemulsification were discarded, resulting in environmental impact [28]. The Aravind Eye Care System and other low-income countries routinely reuse surgical materials (after proper sterilization) with minimal rate of endophthalmitis [29].

### COVID-19 possible outcomes

**Benefit: reduction of air pollutants through medical planning** The American Academy of Ophthalmology (AAO) had provided recommendations and guidelines for ophthalmologists around the world during the COVID-19 pandemic. Initial reduction of elective procedures and less-crowded offices were inherently safer for the patient, the ophthalmologist, the staff, and the environment.

**Disadvantage: aftermath of recession** US Treasury forecasted unemployment in the USA could reach 20% due to COVID-19. At the end of March 2020, the Department of Labor published data showing that the unemployment rate reached 4.4%, among all major worker groups. Several comprehensive and multi-specialty ophthalmology practices closed their offices and laid-off a few of the staff (personal communications). Others remained open for urgent visits and procedures or care for the patients through telemedicine services. Instead, most retina practices continued seeing patients at high risk of blindness, taking all the precautions needed to prevent the spread of the disease, limiting their regularly high volume of patients. On average, retina practice volumes declined between 40 and 70%.

The job market seems to be uncertain in the near future too. An article published in 2009 concluded that the job market in ophthalmology is affected for 2–3 years following a recession [30].

## Conclusion

The healthcare industry is the second-largest greenhouse gas polluter after the food industry. Although greenhouse emissions may drop after the COVID-19 pandemic, their effect on air temperatures would take 40 years to centuries to perceive changes considering how long the gases persist in the air. If the emissions return to the pre-pandemic levels after the resolution of the crisis, the progress made would have been undermined.

Anthropologically, societies are transformed if a pandemic kills a considerable proportion of the population, unleashing the economic pressures of less productivity and higher consumer prices. At the moment, the total repercussions of the COVID-19 pandemic are yet to be determined. In the meantime, digitalization has been accelerated to optimize services and to mitigate the intrinsic difficulties of social distancing. For doctors, including ophthalmologists, the sequel might require drastic changes in how we practice medicine. Nonetheless, if fundamental lessons are learned, we will start taking responsibility for climate change with promising positive outcomes for the entire humanity. In the end, resilience in the midst of a catastrophic event is the only way forward.

**Availability of data and material (data transparency)** Not Applicable

## Compliance with ethical standards

**Conflicts of interest/competing interests** Not Applicable

**Code availability (software application or custom code)** Not Applicable

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