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Impact of climate change and related environmental factors on eye health in India - A narrative review

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ABSTRACT

Climate change and related environmental factors like air pollutants, heat wave, UV radiation, smoke, greenhouse gases, bacteria, viruses, humidity, and temperature variation have considerable impact on human health and also on ocular structures like cornea, conjunctiva, and retina. Due to urbanization, deforestation and industrialization, in middle income developing countries like India, the effect of climate change on human health and eye health is even more causing significant increase in health-related costs. Eye is the most sensitive and vulnerable organ exposed to environmental insults resulting in many eye diseases like cataract, pterygium, glaucoma, neoplasia and dry eye. Moreover, diversity of Indian climate and the changes in the climate is giving rise to many emerging eye diseases and is also increasing the prevalence of many preexisting ocular conditions. Therefore, the main aim of this literature review is to highlight the impact of climate change in overall eye health and to report literature on the same in Indian context.

Key words: *Climate change, Eye health, Indian climate, Environmental factors, Eye diseases*

Introduction

Over a last couple of decades climate change has become the most serious environmental concern and a big threat to all lives on earth. Climate change and related environmental factors like air pollutants, heat wave, UV radiation, smoke, greenhouse gases, bacteria, viruses, humidity, and temperature variation have been reported to cause considerable impact on human health and eye health. In India, the effect of climate change on human health and eye health is reported to be even more. Eye is the most sensitive and vulnerable organ exposed to environmental insults resulting in many eye diseases like cataract, pterygium, glaucoma, neoplasia and dry eye. Thereby, in the present review, we will discuss the impact of climate change in overall eye health and will further discuss the reported literature on the same in Indian context.

Impact of climate change and environmental factors on eye health

Climate change has been reported to cause a major effect in eye health. It has been found that, heat wave can effect the inflammatory process of cornea (Tsai *et al*., 2013). This can be a predisposing factor for viral, bacterial, fungal infections of the eye along with allergic reactions. (Kawai *et al.*, 2020). The increase in the level of UV radiation can cause reduction in cell immunity and increase susceptibility to

various infections and inflammation of eye. UV radiations also can activate various latent viruses (Caspi, 2010). Increase in UV radiations along with heat waves triggers risk of developing ocular tumors, cataract and retinal disorders (Kawali *et al*., 2020; Schehlein *et al.,* 2021). Similarly air pollutants like acrolein and formaldehyde, Particulate Matter [PM]-10 mm and 2.5 mm can be predisposing factors in various ocular conditions ranging from ocular surface disorders to cataract and glaucoma.

The effects of environmental factors on various ocular structures are discussed briefly (WHO. Infectious Diseases, 2020 and Kauser *et al.,* 2019, Gupta *et al*., 2018):

Pre corneal tear film

Immediate impact of exposure to airborne toxins in eye health includes redness, watering, burning and discomfort. Frank and Skov, 1991 have suggested that the poor quality of environmental air can lead to premature break-up of the pre-corneal tear film including some amount of corneal epithelial damage which can further cause significant ocular irritation and discomfort. Association between air pollution and compromised pre corneal tear film was further established in many studies. Air pollutant such as acrolein and formaldehyde releasing from fumes of house hold cooking, firecrackers, wielding, biomass burning, combustion causes alteration of cytokine concentration in tears that leads to increase the lipid oxidative stress on ocular surface causing dry eye. Dry eye disorder is also found to be associated with air pollution due to organic and inorganic particulate matter, humidity and temperature. Individuals with dry eye disorder suffer from symptoms like redness, watering, irritation, burning sensation, foreign body sensation, strain and photophobia. A study conducted in 2003 have long back indicated a possible association with subclinical ocular surface changes caused by air pollution in Delhi which is considered one of the most polluted metropolitan cities of the world.

Conjunctiva and Sclera

Conjunctiva is the loose connective tissue that covers the surface of the eye ball. It protects the underneath tissue from the pollutants and hazards. Long term exposure to UV radiation can cause Pterygium which is a fibrovascular benign growth of the conjunctiva. Previous studies have strongly associated Chronic UV radiation exposure as a risk factor of developing Pterygium in outdoor workers. Pterygium can further progress from conjunctiva towards cornea and in advance cases can even interfere with the central part of cornea obscuring the visual axes. Thus apart from inducing significant amount of corneal astigmatism, it can lead to significant visual disturbance, irritation. Similarly, Pinguecula, fatty – fibrous lesion of the conjunctiva is also thought to be related with exposure to UV radiation. Allergic Eye Diseases like allergic conjunctivitis, vernal keratoconjunctivitis that show high prevalence in recent years are thought to be attributed to the climate changes. These conditions shows symptoms like redness, irritation, itching , watering, swelling of eyelids more common in children and are found to be associated with sunlight, dust, wind, pollen, temperature and ground level ozone. Ocular surface squamous neoplasia is also found to have positive correction with UV exposure. Similarly, basal cell carcinoma and squamous cell carcinoma of conjunctiva is thought to be associated with chronic exposure to UV and ionizing radiation. UV radiation having immune-suppression effect can also reactivates latent viruses like HPV, decrease tumor immune surveillance that leads to increase in number of cell division and metastasis. Similarly UV radiation is also reported to cause episcleritis, an inflammation of episclera. However, no major effect of climate change on sclera has been well established.

Cornea

Avascular and transparent cornea acts as a powerful refractive media with fixed focus. Inflammatory conditions such as corneal epithelium squamous metaplasia can also results from exposure to air pollutants, PM_{10} and $PM_{2.5}$. In this condition transparent cornea shows pigmentation, vascularization and keratinization. Other inflammatory conditions of cornea that are attributed to climate change include dry keratitis and marginal keratitis. Similarly, fungal infection like fungal keratitis that can lead to vision threatening condition shows increased prevalence due to increased CO_2 emission, temperature alteration due to climate change. Various viral infections of eye like herpes simplex, herpes zoster which can cause inflammatory conditions of eye like keratitis, uveitis, scleritis, optic neuritis, choroiditis can be triggered with exposure to UV radiation and increased ambient temperature. Spheroidal degeneration also named as climatic droplet keratopathy, mostly observed in arctic and tropical countries is

positively correlated with the UV exposure. Spheroidal degeneration shows accumulation of spherical opalescent droplets which form bands or nodules with elevated corneal epithelium.

Crystalline Lens

Crystalline lens is the transparent refractive structure of eye. Opacification of crystalline lens is termed as cataract. Although cataract is usually a physiological process that takes place with increasing age, environmental factors like sun exposure, air pollution can be considered as risk factors of developing cataract. Depending on the position of development of cataract it can be of many types like nuclear cataract, cortical cataract, polar cataract, subcapsular cataract, pseudo exfoliation cataract. World Health Organization (WHO) has reported that ozone depletion has a direct association with cataracts. Loss of the ozone layer can lead to increase exposure to U V radiation. WHO has estimated 20 percent of cataract cases are due to the overexposure to UV radiation. It has been observed that there is positive association between nuclear cataract and UVR exposure, smoking and exposure to indoor smoke. Posterior sub capsular cataract and cortical cataract are also found to be associated with UV radiation exposure. It has also been assumed that chronic heat exposure could induce cataract.

Choroid, Iris, Ciliary body

While choroid, the middle pigmented layer of the eye rich with blood vessels nourishes the retina, iris control the amount of light that enter the eye and ciliary body hold the lens and produces aqueous humuor. Choroid, ciliary body and iris together are called uvea. Uveitis is an inflammatory condition of the choroid, ciliary body and iris. Causes of uveitis include infectious conditions of eye found in toxoplasmosis, herpes zoster and herpes simplex, chlamydia. Non-infectious conditions associated with systemic diseases like multiple sclerosis, rheumatoid arthritis, sarcoidosis, multiple sclerosis can also cause uveitis. All these types of uveitis shows increase incidence rate with increase in temperature due to climate change. Furthermore, increased exposure to U V radiations are also thought to be associated with uveitis. Similarly Air pollutants, UV radiation also increase the risk of developing tumors of different ocular structures like choroid, iris, ciliary body. For example, an increased exposure to UV radiation has been associated with choroidal and ciliary body melanoma.

Retina

Retina is the light sensitive inner most layer of the eye. It is composed of photoreceptors cells and glial cells that captures light energy and transmits it to neuronal pathways as both electrical and chemical signals that travel to brain to be perceived as a visual picture. Although, the amount of UV radiation that reaches the eye is significantly less compared to lens, chronic exposure to UV radiation has been established as a risk factor in age related macular degeneration (AMD), a major cause of visual impairment and blindness in elderly population. It has been reported that UV radiation can induce apoptosis of retinal pigment epithelium causing increased possibility of AMD. Other retinal disorders that could be associated with climate change and related environmental factors include tractional retinal detachment, retinal tear, and central serous retinopathy.

Glaucoma

Glaucoma is a vision threatening condition that can lead to blindness if left untreated specially after 5th decade of life. Glaucoma is caused due to increased intra ocular pressure that results in damage to the optic nerve and reduction of visual field slowly progress to blindness. It has been reported that over exposure to particulate matter (PM) of air can raise the risk of glaucoma especially chronic primary angle closure glaucoma and acute glaucoma.

Climate change in India and its effect on health and eye

India with its increasing population and urbanization is undergoing major changes; climate change further pose as an inducing factor that is expected to significantly increase existing health threats of Indians (Bush *et al.*, 2011). Climate changes and associated environmental factors such as extreme heat waves, extreme weather events, variable precipitation patterns, and ozone layer depletion are assumed to cause significant impact on the health and wellbeing of Indians (Majra and Gur, 2009). Likewise, all these environmental factors like toxic gases, pollutants, UV radiation, heat wave, smoke, cosmetic fumes; humidity can affect various structures of eye. The photochemical components due to air pollution is found to effect human eye by changing the PH and concentration of enzyme lysozyme in

the tear film causing eye irritation which also subsequently results in corneal epitheliopathy (Johnston *et al.,* 2012). The increased level of air pollutants like Particulate Matter [PM] -10mm and 2.5mm that are present in tobacco smoke, smog, can cause health problems like premature mortality due to carcinogenic effect [according to WHO] whereas PM pollutants may also cause burning sensation, irritation and allergic reaction in the eye (Schulze *et al.,* 2017; Saxena *et al.,* 2003). Air pollutant such as acrolein and formaldehyde releasing from fumes of house hold cooking, firecrackers, wielding, biomass burning, combustion causes alteration of cytokine concentration in tears that leads to increase the lipid oxidative stress on ocular surface causing dry eye (Veena *et al.,* 2013; Bush *et al.,* 2011). A study conducted in 2002 have long back indicated a possible association with subclinical ocular surface changes caused by air pollution in Delhi which is considered as the most polluted metropolitan city of India. A total of 400 study subjects were divided into study and control groups. The study group comprised of subjects who were exposed to environment pollutions for more than 10 years whereas the control group was comprised of subjects who were not exposed to significant veculiar or industrial pollution for more than 10 years. Clinical parameters such as tear film break up time, Schirmer's were significantly reduced in the study group showing compromised pre corneal tear film in the study population (Gupta *et al.,* 2002). Similarly, air pollutant such as NO, NO2, Ozone, hydrogen sulphate, Carbone monoxide, dioxin chlorofluorocarbons, benzene, arsenic, asbestos, Sulphur dioxide, and particulate matter causes several complications in ocular surface, cornea, and conjunctiva and can also lead to disorders like cataract, conjunctivitis, dry eye, glaucoma (Gupta *et al.,* 2002; Ravilla *et al*., 2016; Sehgal *et al*., 2014). In another study, with 520 study subjects, Gupta *et al.* (2007) reported that individuals who were traveling in highly polluted areas of Delhi and thereby exposed to an increased level of air pollutants exhibit significantly high incidence of subclinical ocular surface disorders. Furthermore, air pollutants have also been proved to increase the allergic eye diseases in children and adolescents (Sehgal *et al.,* 2014). A cross sectional study with 2494 study subjects who were diagnosed with AED and hailed from the district of Hyderabad, a southern city of India, association between several environmental parameters such as rainfall, temperature, humidity, wind speed, and the pollution parameters of PM10, $PM_{2.5}$, CO, NO_2, SO_2, and O_3 and occurrence of AED were explored. The study has reported that environmental factors such as rainfall and humidity was negatively correlated with allergic eye diseases

Table 1. Indian Studies that have reported about the impact of climate change and related environmental factors

Author	Outcome measures	Conclusion
Vashist *et al*., 2020	Lifetime sun exposure hours, smoking, indoor kitchen smoke exposure and their association with cataract and subtypes	Significant association found between cataract and smoking, indoor kitchen smoke and Sun exposure.
Gupta *et al*., 2002	TBUT, Schirmer's test, Ocular subjective complaints of dry eye	Exposure to high air pollutant showed increased chance of ocular surface disorder
Das and Basu, 2021	Temporal pattern of allergic eye diseases (AED), Humidity, rainfall, ground level ozone, temperature, PM 10, $PM_{2.5}$, CO, NO_2, SO_2	Temperature and ground level ozone showed positive correlation with AED. Humidity and rainfall showed significant negative correlation with AED.
Kauser *et al*., 2019	Age, gender, laterality, anatomical position (ant./post./int.), seasonal variation, etiological variation of uveitis	Occurrence of uveitis was more in winter compared to summer season.
Ravilla *et al*., 2016	Lens opacities grading using Lens Opacities Classification System III, biomass fuel years, Midday Sun exposure, alcohol and tobacco use, socioeconomic status, gender.	Smoke caused by biomass cooking fuel was positively associated with posterior subcapsular cataract and nuclear cataract.
Gupta *et al*., 2007	TBUT, Tear lysozyme activity, Schirmer's test	TBUT and Schirmer's found abnormal in the subjects living in metropolitan cities. Tear lysozyme also found to be low in the same group.

(AED) whereas temperature and ground-level ozone was positively associated AED among children and adolescents (Das and Basu, 2021). Occurrence of Uveitis was reported to more in winter compared to other seasons in 100 patients from Delhi. Although the authors of the study could not report a statistical significant result, a possible association between uveitis and seasonal variations were explored (Kauser *et al.,* 2019).

A recent study conducted by Vashit *et al.* (2020) has associated nuclear sclerosis and cortical cataract with different environmental factors including sun exposure, indoor smoke and smoking. In a population of 9735 subjects recruited from different parts of India, a questionnaire based evaluation and a detailed ophthalmic assessment was carried out to prove UV radiation and smoke as the significant risk factors for developing cataracts (Vashit *et al.,* 2020). In another population based study, biomass cooking fuels are proved to be associated with cataracts in women. In a study with 7518 individuals recruited from southern and northern parts of India, it has been reported that biomass cooking fuels that are used in Indian house hold can significantly increase the risk of nuclear cataracts (Chandran *et al.,* 2017). A previous research that investigated the overall health impact of biomass cooking fuels have also reported cataract as a major impact of biomass fuel on women health (Sahu *et al.,* 2013).

Furthermore, reduction in food production which could be an indirect effect of climate change causing calamities like draught may result in malnutrition and undernutrition. Malnutrition causes ocular complication like xeropthalmia due to vitamin A deficiency, especially in children below 5 years of age. Xeropthalmia if not detected and treated early may also lead to blindness (Chandran *et al*., 2017; Pond, 2005), whereas; malnutrition in adults can lead to eye diseases like cataract, AMD, and glaucoma.

Outdoor workers like farmers, daily workers suffer more due to heat wave which reduces their productivity (Sahu *et al.,* 2013). They are having more possibilities to develop ocular complications as an effect of pollution.

Water pollution in ponds and rivers also shows adverse effect in eye and found to cause many infectious waterborne eye diseases due to swimming and bathing (Anderson, 1986). Chlorine used in swimming pools are having more toxic effect in eye and it is found to compromise the ocular immunity (Pond, 2005; Anderson, 1986). Indian studies that have reported impact of climate change and related environmental factors are summarized in Table 1.

Conclusion and Recommendation

Although, there are several researches on climate change and its ocular health, the literature on effect of climate change on eye health and its economic burden is lacking in developing country like India. Six reported literatures discussed in this review showed significant impact of environmental factors on eye health of Indians including ocular surface disorder, increase in allergic eye diseases, cataracts and uveitis. These effects of climate change on ocular diseases can be managed with solution of the approachable level variables like excessive sun exposure, pollution effect, high temperature, excessive rain etc. For example, use of protective eye wares, contact lenses that block UV radiation should be encouraged. Furthermore, interdisciplinary studies including ophthalmologist, optometrist environmental scientist need to be conducted to comprehensively evaluate the environmental impacts on ocular health and treatment and management strategies to establish the economic balance in adaptation of the mitigation measures in Indian population.

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