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MINI REVIEW

# Exposure to Urban Air Pollution Particulate Matter and Ocular Disorders

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## ABSTRACT

About 90% of the world's population is exposed to air pollutants beyond the limits of the World Health Organization (WHO) recommended. Due to regular contact of atmospheric air with the cornea, tear the film, and conjunctiva, the pollutants present in the air have direct access to these ocular structures. Exposure to different parts of the eye to polluted air results in burning and redness of the eye, ocular disorders, and several other problems. Several studies have shown the drastic impact of air pollution on the eyes. In addition to these short-term effects, air pollution can also affect eyesight. Recently studies have linked air pollution exposure with the risk of glaucoma. Based on these findings of inner retinal changes, the Exposure to urban air pollution particulate matter and ocular disorders suggests that PM2.5 may be an independent risk factor for glaucoma. The effects of air pollutants on the eyes are thought to be limited to the surface of the eye and simple eye irritation. While exposure to air pollution has a much greater impact on the eyes than we think. In this mini-review, we investigated ocular disorders following exposure to air pollution particulate matter.

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## Introduction

Air pollutants are a mixture of thousands of compounds including Carbon Monoxide (CO), Ozone ($O_3$), Nitrogen Oxides (NOx), Sulfur Dioxide ($SO_2$), Volatile Organic Compounds (VOCs) and Particulate Matter (PM) [1]. The relationship between air pollutants and human health has been studied for decades. These adverse health effects on humans include acute and chronic effects. Almost all systems of the human body can be affected. There was considerable evidence that air pollutants can have serious consequences for human respiratory and nervous health systems [2-5]. Retinal tissue and optic nerve are considered as part of the Central Nervous System (CNS) because their growth is the protrusions of an embryonic brain [6]. However, the eyes are often a neglected organ in environmental medicine. Most people predict that the effects of air pollutants on the eyes are limited to the surface of the eye and simple eye irritation. In fact, air pollutants have a much greater impact on the eyes than we think. Eyes, which are only protected by a thin layer of the tear film, are very sensitive to external factors [7]. If the PM concentration in the air is high, it can cause clinical manifestation even on the same day. Conditions associated with air pollution are primarily: red eye syndrome, eye irritation, conjunctivitis, dry eye syndrome, discomfort, and meibomian gland dysfunction. A high concentration of PM in the air causes a narrowing of the retina's vessels, which leads to disorders in its microcirculation. Air pollution PM causes a toxic effect on the conjunctiva. The connection between air pollution and cataract is also being studied [5,7]. In this mini review, we examine some of the acute and chronic health effects of exposure to particulate matter on the eye (Figure 1).

### Exposure to PM and eye surface disorders

Exposure to air pollutants due to direct contact with the surface of the eye can lead to eye irritation and significant discomfort. Approximately half of people

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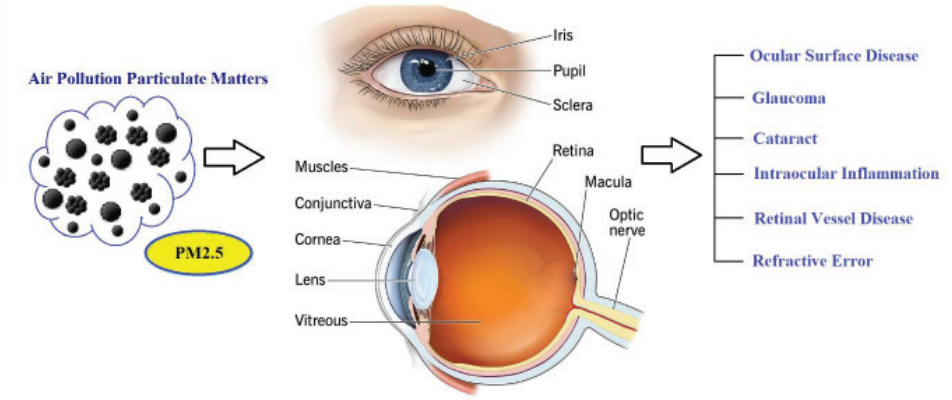


**Figure 1** Acute and chronic health effects of exposure to air pollution particulate matter on the eyes.

exposed to higher levels of air pollutants complained of redness and burning of the eyes [8]. In addition, air pollutants lead to irritation and disturbances of the eye surface not only in the ambient air, but also in the indoor air environment. For those workers in buildings, indoor air pollutants, including gaseous and particulate pollutants, are one of the causes of the symptoms of sick building syndrome [9]. The results of a study showed that air pollutants actually have significant effects on the incidence of dry eye without delay [10]. In a study in Japan, this significant association was shown between exposure to PM and allergic conjunctiva without delayed effects [11]. In addition, not only for allergic conjunctivitis, similar results were reported for nonspecific conjunctivitis in a study from Taiwan. In that study, gaseous pollutants and airborne particles increased the risk of nonspecific conjunctivitis and these effects had no time lag [12]. The effect of non-delay observed in all the above studies was consistent with the results of the Paris study, which shows that the levels of air pollution are associated with an increase in emergency room visits [13]. Accordingly, many population-based studies support the belief that the ocular surface effect associated with air pollution is acute and has almost no time-delay effect. The following are possible mechanisms of ocular surface disorders. The tear layer, as the outermost layer of the eye surface, plays an important role in eye irritation and discomfort. For people exposed to air pollutants, tear evaporation rate, TBT, and corneal staining rates can be significantly worse. The alternation of tear cytokines and the microstructure of the eye surface may lead to lacrimal layer problems for possible reasons. Increasing the concentration of tear chemicals explained the functional changes in tear lipids and their proliferation [14]. In addition, for tear physiology, the increase in a number of chemical factors associated with inflammation at the surface of the eye after exposure to air pollutants confirmed that exposure to air pollution increases the conjunctival inflammatory levels of individuals [15]. In an animal study to examine PM-induced conjunctivitis, higher goblet cell densities were observed, along with strong eosinophil infiltration into the conjunctiva. These findings confirm the change in the structure of conjunctival tissue after PM exposure [16]. In recent years, there is evidence at the molecular biological level that particles in the air may cause cell death in the human corneal epithelium [17].

## Exposure to PM and blepharitis

In addition to changes in the corneal, conjunctival, and lacrimal epithelium, which in turn can lead to irritation, redness, and discomfort of the eye, exposure to air pollution PM is associated with blepharitis, which is associated with acute signs and symptoms on the surface of the eye. In one study, an increase in PM and CO concentrations was associated with an increased incidence of blepharitis without delay effects [18].

## Exposure to PM and Retinal Vessel Narrowing

Both adults and children are prone to these health effects. The effect of air pollutants on the retina is on the microvascular structure. In one study, an increase in PM10 monitoring data was associated with a decrease in Central Retinal Arterial Equivalent (CRAE) and Central Retinal Equivalent (CRVE). The effect can be seen after days of exposure to PM air [19]. The effects of retinal microvascular narrowing have also been observed in children due to the smaller particles, PM2.5. Another study involving repetitive retinal microvascular measurements was performed in children. The results showed that increased PM2.5 exposure on the same day was associated with narrower arterial/venous structures of the retina [20]. The suggested mechanisms, in this case, are that air pollution causes systemic inflammation. Another study suggested that PM affects miRNAs and that miRNAs are more likely to lead to inflammation and oxidative stress [21]. This inflammatory condition caused vascular endothelial dysfunction. The second possible mechanism is that air pollution causes sympathetic nerve activity and thus causes vascular smooth muscle contraction [20].

Chronic exposure to total hydrocarbons and non-methane hydrocarbons increases the incidence of Central Retinal Artery Occlusion (CRAO). In addition to CRAO, airborne contaminants also lead to Central Retinal Vein Occlusion (CRVO). The possible mechanism of chronic air pollution exposure in retinal vessels is systemic inflammation that may cause endothelial dysfunction. Systemic inflammation also increases coagulation, and inflammatory cytokines, including interleukin-1 beta, tumor necrosis factor-alpha, and interleukin-6, activate external coagulation. They also reduce tissue-type plasminogen activators and inhibit fibrinolysis [22]. In a population-based study, the relationship between short-term and long-term levels of air pollutants and microvascular characteristics was investigated using arterial vessel width as measured by retinal color images. A decrease in CRAE was observed in the presence of PM2.5 levels [23]. Air pollutants appear to have chronic effects on retinal vascular changes not only in adults but also in children. By measuring recent exposure (same and previous day) and chronic (annual average) exposure to air pollutants, the results showed significant acute and chronic effects on children living closer to the main road. There are and children experience narrower arteries [20]. Narrowing of the retinal arteries, both arteries, and veins, can be even worse in other conditions and eventually lead to retinal artery occlusion. Which has been proven by various population-based studies. The risk of starting CRAO increased significantly over a period of less than 1 week, following a 1 PPM increase in $NO_2$ levels [9].

### Exposure to PM and myopia

In recent years, there have been population-based studies that show an association between air pollution and the progression of myopia. The likelihood of myopia increases with exposure to higher levels of PM2.5 and NOx concentrations. According to the results of animal studies, exposure to airborne particles leads to increased inflammation and further development of myopia [24]. In the study of the causes of myopia in the elderly 50 years and older, it was observed that exposure to particulate matter and O3 in the air is associated with an increase of more than ten percent in the prevalence of myopia [25]. In investigating the relationship between exposure to urban air pollutants and children, oxidative stress and systemic or local inflammation were suggested as possible mechanisms of how to develop myopia due to exposure to air pollutants. Nitrogen dioxide and PM were significantly associated with the occurrence of myopia [26].

### Exposure to PM and glaucoma

Glaucoma is a common age-related degenerative neuropathy and one of the leading causes of global blindness. Increased Intraocular Pressure (IOP) is the most important modifiable risk factor for glaucoma and is sufficient to cause disease but is not necessary [27]. The exact etiological mechanisms involved in glaucoma are still unclear. People living in urban areas are 50 percent more likely to develop glaucoma than those living in rural areas, which makes air pollution a potential risk factor for glaucoma [28]. Recently, a link between glaucoma disability and national PM2.5 levels has been suggested [29]. Some pathophysiological mechanisms such as inflammation and increased oxidative stress are common in diseases of the cardiovascular and central nervous systems and glaucoma [30]. If air pollution is adversely associated with glaucoma, a new and potentially reversible risk factor may be added to air pollution reduction campaigns. Carbon monoxide is associated with glaucoma control by affecting intraocular pressure [31]. Apart from intraocular pressure, air pollutants can affect glaucoma control in a variety of ways. Ozone, NO and PM were found to be associated with Endothelin-1 (ET-1) system regulation. Increased ET-1, which can lead to vascular dysfunction, was a suggested reason for the progression of early wide-angle glaucoma [32]. Further exposure to PM2.5 was associated with glaucoma and adverse structural changes. Intraocular pressure suggests that this relationship may occur through a non-pressure mechanism, possibly neurological and / or vascular effects [33]. Also, the results of a cohort study on ten thousand children showed that exposure to airborne particles increase the incidence of glaucoma in childhood [34]. Recently, a new association has been reported between increased exposure to environmental PM2.5 and an increased risk of glaucoma. Internal retinal changes, as seen in glaucoma, were greater in people exposed to higher levels of PM2.5. These results suggest that exposure to PM2.5 air pollutants may be an independent risk factor for glaucoma, possibly caused by a neurovascular mechanism rather than an increase in IOP [33].

## Conclusion

The eyes are a very vulnerable organ to air pollution. Long-term and short-term exposure to air pollution is harmful. Exposure to high doses of PM and gaseous air pollutants can lead to conjunctival symptoms or dry eyes even on the same day. The lacrimal layer, cornea, and conjunctiva are in constant contact with ambient air, so the tiny PM in the air can directly affect them and interfere with their function. Clinical manifestations of exposure to air pollutants range from ineffective or minimal to chronic discomfort and eye irritation. In those who wear contact lenses, eye irritation is exacerbated by air pollution. The association between poor air quality and the development of conjunctivitis and dry eye syndrome has been extensively investigated and reported. The impact of PM air pollution is not limited to the surface of the eye. There are studies that link exposure to fine PM air pollution with cataracts and circulatory disorders in the retina. Therefore, the most important issue is to provide systemic solutions to reduce engine emissions and other exhausts to minimize air pollution.

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