

How air pollution affects the eyes — a review

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ABSTRACT

The aim of this study is to present scientific reports concerning the influence of air pollution on eyes. Air pollution is nowadays a common problem. The most significant pollutants are carbon monoxide (CO), nitrogen dioxide (NO₂), ozone (O₃), sulphur dioxide (SO₂), particulate matters — PM₁₀ and PM_{2.5}. The main source of toxins in the air are cars, burning of the fuels and burning of the charcoal in household stoves. Most attention is paid to negative effects of air pollution on respiratory system, such as asthma and lung cancer, however, it is worth remembering that influence on the eyes is equally important. Children are especially vulnerable to the harmful effects of air pollution. Anterior segment of the eye is the most exposed. Substances, which are part of the smog have an irritating effect on the surface of the eye, cause disturbances in the tear film and an inflammation. Medical conditions associated with increased air pollution are mainly eye irritation, conjunctivitis, dry eye syndrome (DES), meibomian gland dysfunction (MGB) and blepharitis.

KEY WORDS: ophthalmology; smog; air pollution; conjunctivitis

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INTRODUCTION

Proceeding industrialization and an increase in the number of cars cause excessive air pollution. Other common sources of pollution are the burning of charcoal in household stoves and forests fires. According to the World Health Organization's report from 2016 33 out of 50 most polluted cities in the European Union are located in Poland. Air pollutants which are most dangerous for public health are carbon monoxide (CO), nitrogen dioxide (NO₂), ozone (O₃), sulfur dioxide (SO₂), particulate matters — PM₁₀ and PM_{2.5}. There are numerous proofs that air pollution causes illnesses such as asthma, lung cancer, chronic obstructive pulmonary disease (COPD), cardiovascular diseases, neurological disorders. Less attention is paid to connection with eye diseases. Meanwhile, eyes, which are only protected by a thin layer of tear film are very sensitive to external factors. If the toxins' concentration in the air is

high, it can cause clinical manifestation even on the same day. Conditions associated with air pollution are primarily: eye irritation, discomfort, conjunctivitis, red eye syndrome, dry eye syndrome and meibomian gland dysfunction. High concentration of toxic pollutants in the air causes a narrowing of the retina's vessels, which leads to disorders in its microcirculation. The connection between air pollution and cataract is also being studied. Air pollution causes a toxic effect on the conjunctiva, however, association with conjunctiva's degeneration — pterygium, was not observed.

REVIEW OF THE LITERATURE INFLUENCE ON CONJUNCTIVA

Conjunctiva is mucous membrane lining the eyelids and covering the sclera from the front, where it devolves into the cornea's epithelium. Due to con-

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conjunctivas being richly vascularized and constantly exposed to external factors, they are vulnerable to the adverse influence of bacteria, viruses, allergens, chemicals and air pollutants, which cause its inflammation. Conjunctivitis is one of the most common conditions diagnosed in ophthalmic patients [1], it is estimated that it affects 15–40% of the population in developed countries [2]. Symptoms of this disease are itchiness, burning, lacrimation, reddening of the eyes and severe photophobia. People who live in areas with heavy air pollution experience these symptoms more often [3, 4]. Conjunctivitis can have diversified course, from mild to that jeopardizing the function of the eye. The result of nontreated chronic conjunctivitis can be impairment of the function of conjunctiva's excretive cells, leading to chronic dry eye syndrome; increased tendency to superinfection of the conjunctiva, complications associated with cornea which can cause worsening of vision. On the other hand, excessively long use of steroid eye drops as a symptomatic therapy is also dangerous, as it can result in serious diseases — cataract or glaucoma. Chronic exposure to pollutants present in the air favours cellular damages, such as hyperplasia of goblet cells of the epithelium on the eye's surface [5]. It was stated that exposure to exhaust from diesel engines increases expression of cytokines, chemokines and growth factors in the conjunctiva's epithelium's cells, meaning it activates inflammation in the conjunctiva [6]. A study conducted in China [7] included 9737 patients who visited an ophthalmologist because of conjunctivitis and it compared the number of visits with the concentration of CO, NO₂, SO₂, ozone, PM_{2.5} and PM₁₀ in the air on the day of the visit and on the days before it. It was demonstrated that an increase of the concentration of all above gases by 10 µg/m³ in the air on the day of the admission or on days directly before was associated with an increase of the number of patients checking in with conjunctivitis. The strongest dependence was found between the concentration of sulfur dioxide and conjunctivitis in children aged 2–5 years old. A study conducted in Taiwan [3] checked a connection between visits because of conjunctivitis and a concentration of air pollutants in 2 years period. The researchers found out, that concentrations of ozone, SO₂ and NO₂ had the biggest influence on the occurrence of nonspecific conjunctivitis. Association with the concentration of CO and PM₂ was not found. The influence of NO₂ and SO₂ was bigger in the winter than in the summer. The number of patients' visits was bigger in the winter due to conjunc-

tivitis in all seven compared areas, which varied by climate and population density. A Canadian study [4] which included 77 439 people affected by conjunctivitis, also confirms previous insights. It was observed that substances such as NO₂, SO₂, O₃, and PM_{2.5} are responsible for an increased number of medical appointments in men. In the group of women, it was bigger concentrations of NO₂ and PM_{2.5}. Most of the afflicted patients were under 4 years old. Among 30 833 patients, that checked in to admission room of ophthalmic centre in Paris within a year, 42% were diagnosed with conjunctivitis or comparable symptoms. In this study, a strong association between conjunctivitis and air pollution, especially NO₂ level, was stated [8].

Pterygium is a degenerative lesion of the conjunctiva, mostly associated with chronic exposure to sunlight. The connection between developing a pterygium and level of air pollution is not well studied yet. The population-based study in Korea, which included 23 276 people did not show any association between air pollution and forming or recurrence of pterygium, instead the influence of UV (ultraviolet) light and ageing was observed [9].

DRY EYE SYNDROME

The tear film is composed of three components: aquatic, lipid and mucous. Disorders in production, vaporization or composition of tear film are thought to be a cause of dryness of the eyes. Dry eye syndrome (DES) is the most common ophthalmic condition [10], its frequency is 11–58%. Many factors can have an influence on the occurrence of DES's symptoms: smoking cigarettes, drinking alcohol, low humidity, air pollution, sunlight exposure, wearing contact lenses, sociodemographic factors, ophthalmic surgeries in the past [11]. Schirmer's test and break-up time (BUT) test are used in diagnosing DES. Schirmer's test, with help of a strip, put into the conjunctival sac, allows the assessment of aquatic component of the tear film. The BUT test evaluates the lipid component of the tear film. In people living in the big cities disorders of tear film were observed more often. In inhabitants of polluted metropolis results of Schirmer's test and BUT test were significantly lower than in those living outside of the city (13.4 mm *vs.* 16 mm; 13 s *vs.* 19.2 s). [12] Inhabitants of strongly polluted areas of Delhi in India complained about reddening and irritation of the eyes two times more often than the control group [12]. A study conducted on 55 inhabitants of Brazil showed the association between exposure to a high concentration of NO₂ and

disorders of the tear film and a feeling of eye discomfort [13]. A clinical study conducted by Versura et al. [14] proved that symptoms of dry eye syndrome are connected with levels of air pollution. It mostly concerns wearers of contact lenses, because in this group the influence of air pollution is more visible [15]. Another study held in Southern Korea [11] on 16 824 people showed the connection between high levels of ozone and NO₂ in the air and low humidity and occurrence of DES, however, connection with levels of PM₁₀ in the air was not found. The increase of the ozone's level by 0.003 pm and decrease of humidity by 5% had significantly influenced the intensification of symptoms and increase in the number of DES diagnosis. High level of PM₁₀ and NO₂ in big cities was associated with shortening of BUT, what is an indicator of eyes' dryness. [16] Han et al. [17] compared the influence of particulate matter (PM) in the form of titanium dioxide (TiO₂) on healthy eyes and on eyes with DES on rat models. In the DES group, there were higher concentrations of lactate dehydrogenase (LDH), tumor necrosis factor alpha (TNF α) and indicators of inflammation in the tear film. After the exposure to TiO₂ there was a significant increase in inflammation indicators in both groups, however, the rise was higher in the DES group. It leads to the conclusion that the surface of the eyes affected by DES is more vulnerable to the dust in the air.

MEIBOMIAN GLAND DYSFUNCTION

Meibomian glands are sebaceous glands, whose excretion is the most external component of the tear film, preventing the tears from vaporizing from the surface of the eye. Symptoms reported by patients with Meibomian glands dysfunction (MGD) are itching of the eyes, a feeling of discomfort, a feeling of dry eyes, reddening of the eyes. Same or very similar symptoms affect patients with DES, wherein what is worth mentioning MGD is one of the most common causes of DES. Many factors influence disorders of the glands' function, among others: chronic blepharitis, wearing contact lenses, Sjögren's syndrome, acne rosacea, humidity and quality of the air [18]. A study on 55 people showed a much bigger incidence of inflammation of Meibomian gland in those exposed to high concentrations of NO₂ [13].

BLEPHARITIS

Blepharitis is an inflammatory state covering brims and skin of the eyelids, tarsal glands, and eyelashes' follicles. The cause of blepharitis is mechani-

cal irritation eg. by dust, smoke and also a bacterial infection. The connection between blepharitis and air pollution is not well examined. There was one study on this subject, conducted in Brazil, which included 200 patients [19]. It showed a significant dependence of high concentrations of PM₁₀ and CO in the air on increase of incidence of blepharitis on the day of exposure.

INFLUENCE ON THE CORNEA

The cornea is constantly exposed to external factors, such as air pollutants, UV radiation, and cigarette smoke. Oxidative stress which is an effect of those factors favours damages of cornea and vision impairment. A study stated that PM_{2.5} in concentration between 20 $\mu\text{g}/\text{mL}$ and 200 $\mu\text{g}/\text{mL}$ is genotoxic, it stimulates damages of the DNA and decreases the efficiency of corneal epithelium cells [20].

CATARACT

The frequency of cataract is higher in developing countries, factors that aid its forming are age, sex, smoking cigarettes, exposure to UV radiation, diabetes. Currently, there aren't many proofs connecting cataract with air pollution. There was one study in India, where household burning of the biomass (charcoal, wood, animal feces) used mainly by the poorer social groups, produces the great number of air pollutants. It is estimated that in 80% of households located in the villages the biomass is used for burning in the stoves. This study showed a significant connection between using biomass in household stoves and forming a cataract in women, but not in men [21]. It may be caused by the strong division of social roles in this society, with women spending much more time in the kitchen cooking than men. Another case-control study held in Nepal and India showed that biomass burning in household stoves favours forming of cataract in women who cook on those stoves. In the case of stoves powered by liquefied petroleum gas (LPG) or biogas, the risk of cataract was much less. Lack of ventilation in the kitchen was an independent risk factor for cataract [22].

INFLUENCE ON MICROCIRCULATION IN THE RETINA

Air pollution is an independent risk factor for developing and progression of cardiovascular disease, however, the influence of air pollution on microcirculation is not well examined. Pathologies in retina's blood vessels are comparable to changes in

micro- and macrocirculation of coronary vessels of the heart, furthermore pathological lesions in retinal vessels are an indicator of arteriosclerosis and a risk a factor of developing hypertension in the future. The first study evaluating the association between air pollution and the narrowing of vessels in the retina was conducted in 2010 [23]. It showed narrowing of central retinal arteriolar equivalent (CRAE) by 0.8 μm in response to chronic (2 years long) exposure to $\text{PM}_{2.5}$ in concentration 3 $\mu\text{g}/\text{m}^3$ on the group of 4607 people. Whereas, as an effect of an acute exposure — on a day before the examination to a higher concentration of $\text{PM}_{2.5}$ — 7 $\mu\text{g}/\text{m}^3$ narrowing of CRAE by 0.4 μm was observed. 3 years later Louwies et al. [24] measured the diameter of retinal vessels in 85 healthy individuals and evaluated how short-term exposure to PM_{10} and carbon dust affects them. Narrowing of CRAE by 0.93 μm and narrowing of central retinal venular equivalent (CRVE) by 0.86 μm was observed with every 10 $\mu\text{g}/\text{m}^3$ increase of the concentration of PM_{10} . Every increase of carbon dust concentration by 1 $\mu\text{g}/\text{m}^3$ caused narrowing of CRAE by 1.84 μm . These discoveries attract attention to the fact that not only chronic but also short-term exposure to air pollutants causes abnormalities in the microcirculation of the retina. It may cause disorders in nourishing and oxygenating the retina, which can lead to vision impairment. Retinal microcirculation disorders can also impact on cardiovascular incidents in the future.

CONCLUSIONS

The dramatic rise of air pollution in the big cities all over the world in recent years caused growing concern about its adverse effect on human health. Eyes are very vulnerable to air pollution. Both chronic, long-lasting and short-term exposure is harmful; exposure to a high dose of toxic air pollutants can result in symptoms of conjunctivitis or eye dryness even on the same day. Tear film, cornea, and conjunctiva have constant contact with ambient air, so toxins that it contains can directly affect them and interfere with its functions. Clinical manifestations of air pollutants exposure fluctuate from none or minimal influence to chronic discomfort and irritation of the eyes. In those wearing contact lenses eye irritation as a result of air pollution is more intensified. Association between bad air quality and development of conjunctivitis and dry eye syndrome is most broadly examined and reported. Interestingly, the influence of air pollution isn't lim-

ited only to the surface of the eye; there are some studies connecting it with the development of cataract and disorders in microcirculation in the retina. It should be remembered that in case of irritation of the eyes, rubbing the eyes should be avoided, because it favours infections. It is recommended to use moisturizing eye drops, cold compresses can be also used. Children and elderly people should be specially protected, as they are very vulnerable to air pollution. However, the most important issue is to introduce systemic solutions decreasing emission of the engine and other exhaust so that the air pollution can be minimized.

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