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Invited Review Article

Pollution and skin: From epidemiological and mechanistic studies to clinical implications

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ABSTRACT

In recent years, the health effects associated with air pollution have been intensively studied. Most studies focus on air pollution effects on the lung and the cardiovascular system. More recently, however, epidemiological and mechanistic studies suggest that air pollution is also affecting skin integrity.

This state-of-the-art review focuses on this latter aspect; it was developed with the collaboration of European and Chinese board of experts with specific interests in environmental health, clinical and basic research in dermatology and cosmetic dermatology. A literature review limited to pollution and health effects and (sensitive) skin was performed using PubMed. Review and original articles were chosen.

We summarize the existing scientific evidence that air pollution exerts detrimental effects on human skin, discuss potential clinical implications and suggest specific and unspecific cosmetic protective measures.

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Abbreviations: AhR, arylhydrocarbon receptor; PM, particulate matter; PAN, peroxy acetyl nitrates; MDA, malondialdehyde; MMP, matrix metalloproteinase; PAH, polyaromatic hydrocarbons; UV, ultraviolet radiation; VOC, volatile organic compounds.

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1. Introduction

Recently, published figures from the 2012 WHO Air pollution report 3.7 million deaths are attributed to ambient air pollution worldwide. This is double previous estimates and places air pollution as the world's largest single environmental health risk. Common anthropogenic pollutants arise from household combustion devices, motor vehicles, industrial facilities and forest fires. Outdoor air pollutants of major public health concern include particulate matter, volatile organic compounds, ozone, nitrogen dioxide and sulphur dioxide. Composition and concentrations vary in both developed and developing countries. In some regions, household air pollution remains mainly a rural issue, while ambient air pollution is predominantly an urban problem. Also, in some continents, many countries are relatively unaffected by household air pollution, while ambient air pollution is a major concern [1].

Researchers are increasingly interested in the various effects of pollutants on human health. Recently, large epidemiological studies identified that both long- and short-term exposure to air-borne pollution, including exposure to both particulate matter and ozone increases respiratory and cardiovascular morbidity [2,3]. Long-term exposure has even been associated with the development of certain cancers [4].

Although, epidemiological and clinical studies highlight the adverse effects of pollution on human health, very little research is available to date concerning cutaneous effects. The skin is another organ, of which the outermost barrier is in direct contact with various air pollutants.

Sensitive skin is known to be associated with barrier dysfunction [5] and the prevalence of reported sensitive skin is increasing within industrialized countries including Asian skin types [6–8].

This subgroup within the population may therefore need specific management in urban areas particularly with high levels of ambient pollution.

In this article we attempt to provide a state-of-the-art review on what is currently known about the effects of common pollutants on skin. We will also discuss these data in the context of sensitive skin and eventually would like to suggest some cosmetic measures that could prevent or relief skin damage caused by environmental pollutants. We also believe that this topic might be of particular relevance to countries where mainly fossil fuels are consumed, with a fast growing automobile market and industry.

2. Methods

A Eurasian board of experts was formed at the beginning of 2014, composed of one European Dermatologist and specialist in Environmental Medicine (JK), two Chinese dermatologists (LW, LL), a public health specialist (XP) and three scientists from L'Oreal research (MC, GS, SS). A literature review was performed using PubMed, using combinations of the following words: air pollution, health effects, skin, cutaneous symptoms, respiratory disease, cardiovascular disease, lung cancer, dermatological symptoms, sensitive skin, China, ozone, nitrogen dioxide, air quality, PM_{10}, $PM_{2.5}$, particulate matter, satellite maps, environmental stressors, atmospheric pollution, outdoor pollution, indoor pollution, organic compounds, arylhydrocarbon receptor. The most recent publications were chosen from both review and original articles. The group discussed the literature which was found according to these search criteria and subsequently prepared the present review paper.

3. Key pollutants and worldwide variations and concentrations

The WHO defines pollution as contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere [9]. Pollution is usually related to either an internal or an external environment. Ambient pollution refers to air pollution in outdoor environments and is the focus of this review. Outdoor pollution comes from fixed, usually industrial sources, and mobile sources such as road and air traffic. These sources produce *primary pollutants* of which there are two main groups; particulate matter (PM) and gases (CO_2, CO, SO_2, NO, NO_2, NOx_2) including, light molecular weight hydrocarbons, (volatile organic compounds VOC). Air particles are commonly referred to as fine particles ($PM_{2.5}$) and coarse particles (PM_{10}). Small particles are typically produced by combustion and the larger by mechanical processes that create and suspend dust particles in the wind. However under certain atmospheric conditions, *secondary pollutants* such as ozone and peroxy acetyl nitrates (PANs) form from photochemical reactions between the primary pollutants, heat and UV radiation. These pollutants stay low in the atmosphere (troposphere) and settle over both urban and rural areas forming what is typically known as smog. Dust particles, which would be part of the 'normal' outdoor environment, in some locations, have been found also to be coated with a complex mixture of anthropogenic pollutants and microbial flora and fauna [10,11].

The level of pollution and pollutant concentration varies throughout the day, by season, geographic location and according to the level of human activity. In particular, ozone levels increase during summer, when the strong sunshine enhances ozone production via photochemical reactions between primary pollutants.

The WHO specifies that both small ($PM_{2.5}$)and large particles (PM_{10}) exist in urban environments in concentrations, varying with the types of combustion most often used and local meteorological conditions [9]. The quantity of ground testing varies between countries, rendering comparisons between countries unreliable, particularly for the African continent, where little ground data is available. Therefore, recently, worldwide PM levels have been obtained by satellite imagery. These pictures have shown Northern India and China to have particularly high $PM_{2.5}$ levels, reaching an annual average of over 50 $\mu g/m^3$ [12]. These levels seem to be relatively stable with similar figures being recorded in 2008, 2010 and 2013 [13]. A seasonal effect in China was studied recently by the School of Atmospheric Sciences, Nanjing University and the Jiangsu Provincial Academy of Environmental Sciences. They found in Nanjing, the ambient levels of $PM_{2.5}$ varied from 33 to 234 $\mu g/m^3$ and PM_{10} from 42 to 328 $\mu g/m^3$. These levels are higher than the WHO recommendations (2.9 and 4.2 times). Peaks occur during the winter months where there is less wind and heating is provided by mostly carbon fuel.

Ozone pollution, as indicated by satellite imagery, is mostly a problem in the Northern hemisphere, in general. Nitrous gases, mainly from automobile combustion and industry are generally higher in South American and Asian regions, although some European cities surpass the Environment Canadian 40 $\mu g/m^3$ limit [14]. So, sources of pollution vary between developing and developed countries and pollutant concentrations vary between cities, making pollution a worldwide issue.

4. Health problems associated with pollution exposure

Environmental toxicologists and epidemiologists continue to study the effect of pollution on human health. In Europe, [15] the USA [16] and China [17–19] studies repeatedly show that the acute and long-term effects of ozone and particulate matter exposure are associated with increased cardiovascular [2] and respiratory mortality and morbidity [20]. Additionally, there is growing evidence that other organs might also be affected by