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Omnipresent, dangerous, unknown: what exactly is particulate matter?

The current development of analytical methods has finally opened the door to learning about the chemistry of the organic compounds that form the dust particles floating in the air, claim the authors of a report published in the journal Chemical Reviews. In the light of the latest research the main culprit responsible for creating airbone particulate matter has turned out to be – apart from car engines and furnaces – the seemingly harmless tree.

All around us there is particulate matter in the air. Its microscopic particles are composed of a rich mixture of inorganic and organic chemicals. Despite the growing interest from the world of science and continually developing analytical techniques, the chemical complexity of particulate matter and complicated reaction pathways leading to its formation are largely unknown. The current gaps in this field of knowledge require filling in ever more urgently. Only then will it be possible to understand the complex impact of particulate matter on human health, quality of life and the planet's climate change. These are the conclusions of a comprehensive report published by an international team of researchers in the journal Chemical Reviews, the number two journal worldwide in terms of influence.

“Particulate matter, rich in organic compounds, is literally omnipresent. With each breath we take the chemical components of this cocktail enter our lungs and once there, penetrate cell membranes directly into the bloodstream. Information about what we are really breathing is therefore of absolutely key importance for our lives,” notes Dr. Rafał Szmigielski from the Institute of Physical Chemistry of the Polish Academy of Sciences (IPC PAS) in Warsaw, one of the report's co-authors.

Particulate matter is an aerosol, i.e. an array of multiple solid or liquid particles with diameters not larger than several micrometers (that is over ten times smaller than the diameter of a human hair) dispersed in the air. These particles are composites of hundreds to thousands of chemical compounds: from the very simple, with particles of only a few atoms, to polymer chains of several dozen or more thousand atoms or even fragments of DNA. According to the latest estimates, simple mineral (inorganic) substances constitute far less than half of the components of aerosol particles.

“We now know that particulate matter contains mainly nitrates and sulphates. We also understand where they come from – usually from an entire, very complicated sequence of reactions, as a result of which the nitrogen or sulphur oxides in the atmosphere are converted into acids, or else they are the result of the natural processes of the rock erosion. However, the composition and origin of the main, organic fraction of the ambient aerosol remained virtually unknown until last years,” says Dr. Szmigielski.

The scale of challenges associated with measurements and analysis of particulate matter turned out to be comparable to that of penetrating such exotic environments as the ocean floor or the surfaces of other planets. The researchers had to develop new methods of chemical analysis, as well as adapting existing ones. Today, particulate matter is collected at measuring stations where it settles on special filters. “We have been collecting the aerosol particles for research at the Institute from the air of the cleanest Polish regions, using the most modern dust collectors equipped with quartz filters for this purpose,” explains Dr. Szmigielski. Filters with the concentrated aerosol particles, after isolation from the environment, are transported to the laboratory. Here, the chemical compounds forming the dust are transferred into solutions by means of suitable techniques, after which they undergo testing by ultrasensitive analytical techniques: liquid chromatography coupled to mass spectrometry.

“Liquid chromatography enables us to separate mixtures of organic compounds into their single components, and using mass spectrometry we can determine the molecular weight of each test compound and postulate its chemical structure and elemental composition,” explains Dr. Szmigielski.

The use of liquid chromatography coupled with the mass spectrometer has allowed scientists to better understand the interactions taking place in the atmosphere between the gaseous substances contained within it and the forming dust particles. In cities the role of nuclei, mopping up successive chemicals from the environment, is played by, among others, dust and carcinogenic soot particles arising as a result of the combustion processes of rubbish and contained in exhaust gases, especially those emitted by cold diesel engines. However, recent studies have confirmed the hypothesis formulated half a century ago that, on a planetary scale, an important role in the formation of particulate matter is played by... trees. In the course of evolution, they have developed a smart immune system: while growing they produce large quantities of highly volatile substances which surround the plant with a protective gas cloud. The purpose of these gases – mainly isoprene in the case of deciduous trees and alpha-pinene in the case of conifers – is to deter unwanted insects and trap harmful chemicals before they penetrate into the plant cells. It turns out that nowadays molecules of these compounds act as precursors around which harmful chemicals from human activities condense.

Epidemiological studies show a clear link between the pollution of a given area with the concentration of aerosol particles and the morbidity of people living in that place. The connection is particularly evident in the case of lifestyle diseases, including asthma, allergies, heart disease and various dermatological problems.

“The widely known problems of miners with pneumoconiosis are due to limited periods of exposure to high concentrations of mineral dust containing fairly simple inorganic compounds. In the case of aerosols in big cities we are dealing with a rich cocktail of really harmful chemicals which we breathe in throughout our entire lives. Our exposure is continuous, which means that even quite small concentrations of dust may prove harmful,” says Dr. Szmigielski and stresses: “This is why appropriate education is extremely important, making the inhabitants of a given area aware of the risks associated with the presence of particulate matter and mobilizing local authorities to monitor concentrations and the chemical composition of the dust, and as a consequence, also its sources”.

The multi-page report on particulate matter published in Chemical Reviews was prepared by research teams from Belgium, Denmark, Finland, France, Germany, Norway, Poland, Slovenia, the United States, Great Britain, Italy and Switzerland.

The Institute of Physical Chemistry of the Polish Academy of Sciences (http://www.ichf.edu.pl/) was established in 1955 as one of the first chemical institutes of the PAS. The Institute's scientific profile is strongly related to the newest global trends in the development of physical chemistry and chemical physics. Scientific research is conducted in nine scientific departments. CHEMIPAN R&D Laboratories, operating as part of the Institute, implement, produce and commercialise specialist chemicals to be used, in particular, in agriculture and pharmaceutical industry. The Institute publishes approximately 200 original research papers annually.

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SCIENTIFIC PAPERS:

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LINKS:

http://www.ichf.edu.pl/
The website of the Institute of Physical Chemistry of the Polish Academy of Sciences.

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Press releases of the Institute of Physical Chemistry of the Polish Academy of Sciences.

IMAGES:

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Analysis of particulate matter at the Institute of Physical Chemistry of the Polish Academy of Sciences (IPC PAS) in Warsaw, Poland. (Source: IPC PAS, Grzegorz Krzyżewski)

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Dr. Eng. Rafał Szmigielski from the Institute of Physical Chemistry of the Polish Academy of Sciences (IPC PAS) in Warsaw presents a simple model of aerosol particles. (Source: IPC PAS, Grzegorz Krzyżewski)