Nature, origin and impacts of fine and ultrafine particulate matter in urban outdoor and indoor environments

Atmospheric air pollution is a complex cocktail of chemical species, with particulate matter (PM) being currently the subject of extensive research carried out by scientists from various disciplines worldwide due to its broad spectrum of impacts. In the last decades, high concentrations of PM have caused great public concern due to the increasing awareness of their negative impact on human health. Nowadays, exposure to both ambient and indoor air pollution has been identified as the greatest environmental risk to human health and the fourth-leading risk factor for premature deaths after high systolic blood pressure, tobacco and dietary risks. Latest global disease estimates indicate that more than 4 million premature deaths are caused every year by ambient air pollution, with PM and ozone being of the greatest concern. Among all PM fractions, fine $PM_{2.5}$ (particles with an aerodynamic diameter < 2.5 μm) is recognized as a key air pollutant in terms of adverse health effects, as, when inhaled, they can penetrate to the deep alveolar regions of the lungs and further migrate to the blood system, affecting the whole organism and, in particular, causing cardiovascular, respiratory and cerebrovascular disorders. High PM concentrations are also of great concern to the public due to the increasingly common knowledge about their negative impact on human health. However, due to the heterogeneity of this air pollutant, it is extremely difficult to assess its health impacts as the characteristic of PM depends on its size, shape and surface, as well as chemical and mineralogical composition. Such detailed characteristic of PM is not commonly investigated within the routine air quality monitoring, which also makes it impossible to quantify the sources responsible for the observed PM levels.

Therefore, the research carried out in the project aims to perform a detailed chemical analysis of the different subfractions fine $PM_{2.5}$, i.e. PM_1 ($d_a < 1$ μm) and $PM_{1\text{-}2.5}$ ($d_a > 1$ μm and $d_a < 2.5$ μm), as well as the development of knowledge regarding the characteristic of the smallest ultrafine particles (UFP; $d_a < 100$ nm), which are hypothesized to exert higher toxicity than larger particles. Such an in-depth analysis of PM characteristics will allow identifying the sources of its emission, and further link the distinguished PM types with the negative health effects. To this end, $PM_{2.5}$ and PM_1 samples will be simultaneously collected daily during a measurement campaign lasting 12 months, while the chemical composition of both fractions, including 20 trace elements, water-soluble ions, as well as elemental and organic carbon, will be determined every second day. Identification of PM sources will be carried out applying the advanced receptor modelling method, i.e. positive matrix factorization – PMF, investigating the data on the concentrations of PM_1 and $PM_{2.5}$ and its constituents. Since the smallest UFP particles have a negligible mass but are the dominant contributor to the total number of particles in the atmosphere they are better quantified by the number concentration. Measurements of the number concentrations of UFP particles will be conducted in different parts of Warsaw, as well as during the different times of the day and different seasons of the year. This will allow assessing the temporal and spatial distribution of the particle number concentrations across the city.

The numerous epidemiological studies conducted for seven decades have shown that PM has a significant impact on the occurrence and/or exacerbation of many diseases and disorders, and a wide spectrum of the observed symptoms. The project will attempt to determine to what extent individual fine PM fractions and their components, as well as the identified PM sources contribute to an increased risk of hospitalization and premature death. The AirQ+ software, developed by the World Health Organization Regional Office for Europe, will be used for the calculations, in which the risk of exposure to PM air pollutants in a given population is represented by the concentration-response functions based on the relative risk (RR) estimates derived from epidemiological cohort studies.

As people spend most of their time indoors, where the concentrations of some pollutants are often higher than typical outdoor concentrations, a better understanding of the indoor-outdoor relationship is of importance. Thus, the simultaneous measurements of the particle number and mass concentrations in ambient air and inside different types of buildings will also be conducted in the project, allowing for the characterization of the indoor/outdoor (I/O) ratios for different living and working conditions.

Furthermore, the proposed project aims to evaluate the effectiveness of the local air pollution control policies adopted in Poland at the regional and local levels, in particular with the regard to coal combustion for heating purposes in small scale combustion installations.

The results obtained in the project will expand knowledge in understanding the sources and processes forming PM air pollution in Polish agglomerations, providing scientific knowledge for policymakers to improve the tools for the effective reduction of air pollutant emissions. The dissemination of these results may also bring benefits for raising public awareness of the negative impact of PM air pollution on health.