RESEARCH VIRUS

ENVIRONMENTAL TRANSITION

JEAN-LUC JAFFREZO AND GAËLLE UZU

THE SCIENTIFIC CHALLENGE OF CONNECTING EXPOSURE TO ATMOSPHERIC POLLUTION WITH HEALTH IMPACTS

PUG

The **Environmental Transition** series
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Produced in collaboration with the scientific council on the Green Capital and Transition chaired by Magali Talandier, as part of Grenoble European Green Capital for 2022 – Climate Air Energy Territorial Plan – Grenoble Alpes Métropole.

Published with the support of Banque des Territoires.

ISBN 978-2-7061-5440-9 *(e-book PDF)*
ISBN 978-2-7061-5441-6 *(e-book ePub)*

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www.pug.fr

ENVIRONMENTAL TRANSITION

A SERIES IN THE **RESEARCH VIRUS** COLLECTION

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Under the aegis of the scientific council on the Green Capital and Transition, this new series of e-books offers previously unpublished articles by researchers from many backgrounds: hard science, Earth science, engineering, and human and social sciences.

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Have a stimulating read!

THE SCIENTIFIC CHALLENGE OF CONNECTING EXPOSURE TO ATMOSPHERIC POLLUTION WITH HEALTH IMPACTS

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It is difficult to grasp the question of the tools for observing air quality as a whole, because the composition of the air we breathe is vast and complex. But the policies framed to protect the environment and our health are based on the measurements made by these tools. If, for instance, we look just at particulate matter, there are several ways of observing and quantifying exposure: size distribution; chemical-species content; and mass concentration. But each measurement only takes into account one type of physico-chemical property of the relevant pollutants. Given the considerable diversity of the chemical properties of aerosols, their forms, reactive surfaces, sizes and so on, we cannot reduce the toxicity of the air we breathe to just its mass concentration. This is nevertheless currently the only indicator used to determine the guidelines for protecting public health. Yet breathing in a microgram of sand obviously does not have the same impact on our lungs as the same amount of mercury or lead. Measuring mass concentration is one of the simplest processes to automate, but we need to develop measurements that do more to include the many properties of particles that come into play when they interact with human biology, in order to gain a better understanding of their health impacts.

Developing new air-quality indicators

Airborne particles act on the organism in various ways. Once inhaled some of the fine particles will be deposited on the outer wall of the bronchioles and alveoli, setting in motion several biological mechanisms, which are not yet fully understood. We know, for instance, that the soluble components of particles may reach the blood stream, that some ultrafine particles can pass straight through the respiratory membrane, or indeed that particles trigger nervous system reflexes, leading in turn to reactions in the walls of blood vessels. However we currently think that the main mechanism is the particles' ability to induce oxidative stress, which causes many cardio-respiratory disorders. Under normal circumstances the anti-oxidants present in our cells can counter oxidants before they damage our health. But when oxidant particles in the air we breathe enter our lungs they interact with our natural anti-oxidants and disturb their behaviour.

Initially our anti-oxidant defences come into play. But if oxidation persists anti-oxidant reserves dwindle. Pro-inflammatory mediators are released into the blood vessels, causing inflammation, then cytotoxicity conducive to disorders. The diseases differ from one region to the next, depending on the nature of the particles (whose composition depends on the source of emissions), the duration of exposure, individual susceptibility and other environmental factors to which a given population is subject.

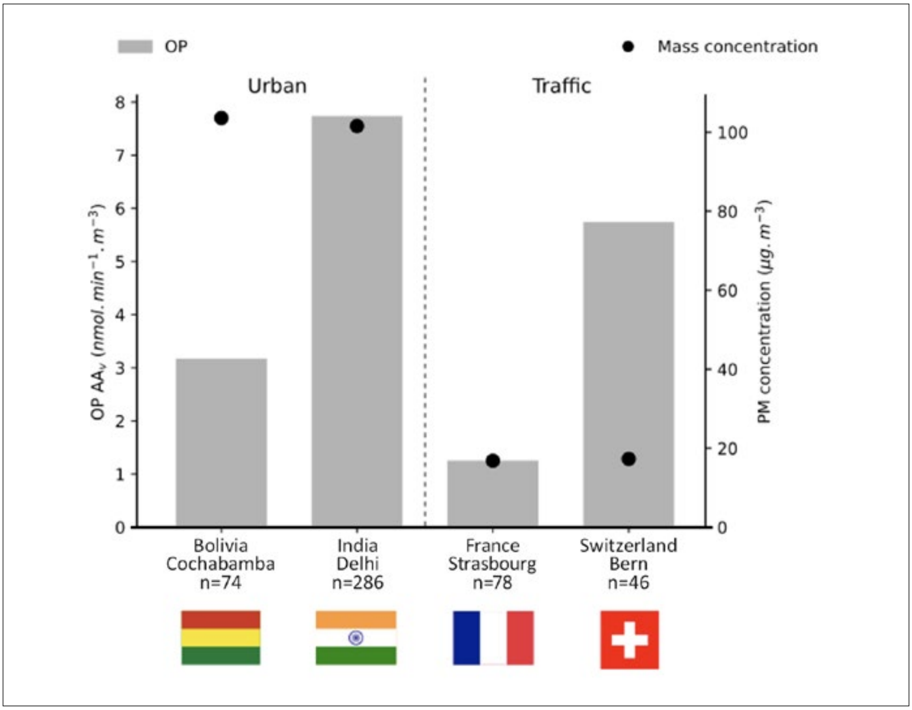
In an effort to make more effective allowance for how particle exposure impacts our health, research groups focusing on atmospheric geochemistry and toxicology have, in the past 15 years, proposed a new measurement known as oxidative potential. It allows us to quantify the effects of inhaling aerosols on pulmonary anti-oxidants, the same ones that protect us against the oxidative damage done by free radicals generated by particles in the respiratory system. It is thus possible assess the impact of the chemistry and solubility of the species present; but also the size and shape of particles by way of their reactive surfaces, or indeed potential 'cocktail effects'. Several tests are possible, using various anti-oxidant molecules.

Among the advantages of this method, its low cost and speed is worth noting, but also its non-intrusive nature and the scope it offers for becoming a routine laboratory process, unlike cellular tests with require tissue samples and the analysis of inflammatory protein biomarkers.

Different types of metrics

Tests have shown that oxidative potential and mass concentration are not always correlated. Here, for instance, is a graph mapping average mass concentration values from four study sites (Bolivia, India, Switzerland and France) analysed by IGE.

Figure 1. Comparison of the metrics for PM mass-concentration and PM oxidative potential (measured using the ascorbic acid method), at two pairs of urban and traffic sites, showing identical average PM mass concentrations (upper and lower), but very different OP results. Measurements made at IGE.



Credits: PSI for the Bern and Delhi sites; LCSQA and Atmo GE for Strasbourg; IGE for Cochabamba.

What does this tell us? Whereas the mass concentration is identical for each of the paired sites – high in Cochabamba and Delhi, low in Bern and Strasbourg – the oxidative potential varies by a factor of between two and three for each pair. The Bern site displays PM_{10} [particulate matter with a diameter of 10 microns or less] concentrations below the regulation threshold, five times lower than the equivalent reading in Cochabamba, yet the oxidative potential of the PM_{10} observed in Bern is actually twice as high. This means that the PM_{10} from the traffic site in Bern have a far greater oxidative effect than in Cochabamba. The impact on public health of the PM_{10} observed in Bern appears to be more damaging than the mass concentration, taken in isolation, would suggest.

There are also sample locations where the two metrics agree: at the Delhi site high PM_{10} mass concentration and oxidative potential levels were observed; in Strasbourg low mass-concentrations values coincided with low oxidative potential. The various results depend directly on the emission sources affecting specific sites, in other words the chemical make-up of the particles.

Displaying the two metrics side-by-side clearly provides a different picture of particle exposure. By measuring only one quantity, particle mass concentration fails to capture the full complexity of the physico-chemical properties of the aerosol.

A new way of seeing particle sources

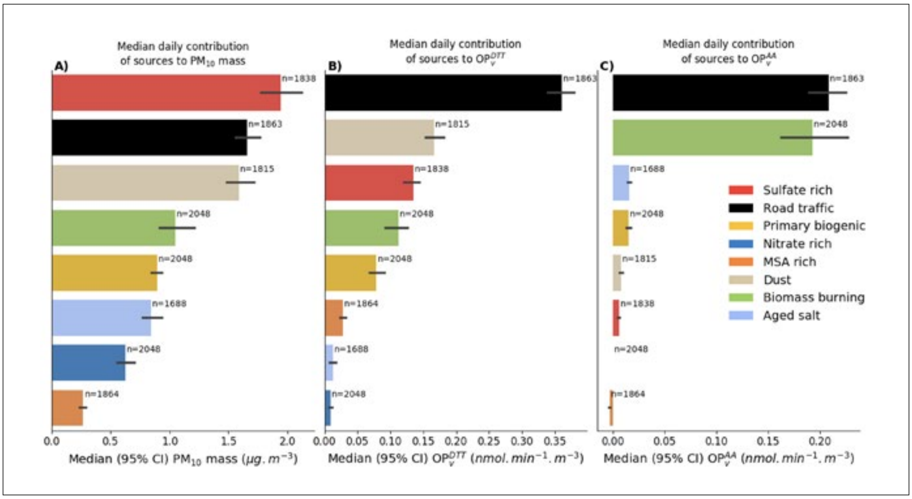
So with regard to the impact of air pollution on public health, we need to rethink the way we use the mass-concentration metric to look at aerosols, because the sources contributing most to particle mass are not necessarily the ones that potentially cause the most oxidation in lungs. Our work now allows us to quantify the contribution of each particle source to the oxidative potential observed at a study site.

In recent years studies of the oxidative potential of particles have shown that two main anthrogenic sources are predominant in the average contribution to oxidative potential: road traffic and burning of household biomass (see Weber *et al.*, 2021)[1]. The part played by wood fires is particularly important in winter, when it combines a fairly high intrinsic oxidative potential (per microgram of particles produced by this source) and high output. So this source is currently one of the main levers for combating atmospheric pollution in suburban and rural areas, particularly in Alpine valleys.

As for chronic exposure (in other words median daily exposure over a year), Figure 2 shows that road traffic is the main source of emissions contributing to exposure to the oxidative potential of aerosols, at 15 urban or suburban sites in France. In our study this is the only source with a very large impact, in terms of both the median and average level of oxidative potential. Primary emissions from road traffic certainly display lower mass concentration values, but they are present all year round.

1. Weber, S. *et al.* (2021a). Source apportionment of atmospheric PM_{10} oxidative potential: synthesis of 15 year-round urban datasets in France, *Atmospheric Chemistry and Physics*, 21(14), 11353-11378. doi.org/10.5194/acp-21-11353-2021

Figure 2. Median daily contribution of sources to (A) PM mass, (B) OP^{DTT}_V and (C) OP^{AA}_V. The bars represent the average; the error bars represent the 95% confidence interval of the median. Figure established for 15 locations in France[2].



So the importance of emissions sources varies a great deal depending on whether the observation metric is PM_{10} mass concentration or oxidative potential. If we assume that oxidative potential provides a clearer indication of particles' impact on public health, because it takes into account a larger number of the properties that account for particle toxicity, then Figure 2 shows that mass is ill suited to the study of air quality, with regard to the impact on public health, which is after all the prime objective of air-quality regulations.

Next steps

The work outlined above partly answers the question of overall exposure to atmospheric pollution in western Europe, but our measurements of the variability of oxidative potential, in space and over time, are limited to the past and to predominantly outdoor, urban settings. So we must bear in mind the local particularities of different sites. Moreover further research is required on the oxidative potential of many occasional sources, such as industrial facilities or ports, which have little statistical weight in terms of space and time.

2. Weber, S. *et al.* (2021a), *ibid.*

Even though measuring oxidative potential looks promising, because it represents a major step forward in interdisciplinary studies of air quality and public health, it is essential to underline the diversity of pollutants yet to be accurately quantified. For instance this metric fails to account for emerging categories such as endocrine disruptors or pesticides.

Many questions raised by our research are still unanswered. Little is known about the links between aerosol chemistry, toxicology and the impact on public health. Before the oxidative potential can be used as a health indicator, a comparative appraisal of the various tests used to measure the damaging effects of poor air quality will be needed. Interdisciplinary studies of this metric and epidemiological data are currently underway in Grenoble (with plans for equivalent studies in other European studies to follow soon). This should also enable us to answer the essential question of which test of oxidative potential is the most effective and harmonize the protocols used by various laboratories. This fast-growing field of research should provide us with a more comprehensive picture of the damage atmospheric pollution does to public health. Our work is very much upstream, but it is designed and built to serve as the scientific basis for future air-quality standards.

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