Unravelling the Health Impacts of Air Pollution with Toxicological Science

Air pollution is an important determinant of ill health. A wide range of adverse effects of outdoor (ambient) and indoor (residential) air pollution on health has been well documented by studies conducted in various parts of the world. The major 'culprits' are particulate matter (PM), ozone and nitrogen dioxide. The adverse effects on health of PM are especially well documented. Although there are various limit values and guideline values in different countries/regions there is currently no reliable evidence that would allow limits on PM to be set with confidence. Pollution from PM creates a substantial burden of disease, reducing life expectancy by almost 9 months on average in Europe. Since even at relatively low concentrations the burden of air pollution on health is significant, effective management of air quality that aims to achieve the concentrations set out in World Health Organization (WHO) Air Quality Guidelines is necessary to reduce health risks as much as possible.

Ozone is a major constituent of photochemical smog. It is generated at ground level by atmospheric reactions of UV light with oxides of nitrogen and hydrocarbons produced by motor vehicles, industry and it seems most types of plants (Vivaldo et al, 2017). Once generated, ozone can travel long distances on air currents, for example, to less polluted regions, where it can accumulate and reach high concentrations far away from the original source. The WHO guideline value for ozone is 100 $\mu g/m^3$ as an average measured over 8-hours. Higher levels of ozone can irritate and inflame the lungs. It can also irritate the eyes, nose and throat, which can lead to cough and chest discomfort. In sensitive individuals, such as those with asthma, ozone pollution episodes can make breathing difficulties worse.

Nitrogen Dioxide is one of a group of gases called nitrogen oxides. Road transport is estimated to be responsible for about 50% of total emissions of nitrogen oxides, which means that nitrogen dioxide concentrations are highest close to busy roads and in large urban areas. Gas boilers in buildings are also a source of nitrogen oxides. There are two WHO guideline values for nitrogen dioxide; 40 $\mu g/m^3$ as a yearly average and 200 $\mu g/m^3$ as a 1-hour average. There is good evidence that nitrogen dioxide is harmful to health. The most common outcomes are respiratory symptoms such as shortness of breath and cough. Nitrogen dioxide inflames the lining of the lung and increases susceptibility to lung infections such as bronchitis. Studies also suggest that the health effects are more pronounced in people with asthma compared to healthy individuals.

Particulate matter (PM) is a complex mixture of finely divided liquid droplets or solids in a gaseous medium. It is released into the air by a variety of combustion sources and it is both the chemical make-up and size of the particles that appear to determine the toxic effects. PM with a diameter of between 0.1 and 2.5 millionths of a metre (PM2.5) is the air pollutant most strongly associated with detrimental health issues. A diversity of adverse health effects recorded in epidemiological studies have contributed to establishing the WHO air quality guideline and various national air quality standards. The WHO guidelines for exposure to PM2.5 are 10 $\mu g/m^3$ as an average over a year and 25 $\mu g/m^3$ as an average over 24-hours.

Having firmly established associations between ambient PM and adverse health effects, the biggest gap in our knowledge of PM toxicity relates to: which component(s) of ambient PM, and/or which of their physical and chemical characteristic(s), are responsible? It is only with this information that it will be possible to develop relevant PM management strategies to more effectively address public health. For example, whilst standards, guidelines and strategies aimed at reducing PM are based on ambient particle mass (which includes a mixture of particles from many sources), this may be insufficient to identify which components in PM are causes of toxicity.

Filling current knowledge gaps

Identification of the toxic components of PM is a challenging task as particulate air pollution constitutes a complex mixture of particles, present in the atmosphere as solids or liquids that vary in mass, number, size, shape, surface area, chemical composition as well as reactivity, acidity, solubility and origin. The challenge of identifying which of the chemical and physical properties of the PM in a mixture are the most hazardous to health is exacerbated in that chemical constituents of individual particles can be internal or on the particulate surface, resulting in a core and a shell having different compositions. Indeed, airborne PM presents a far greater complexity than most other common air pollutants. The identification of PM-specific effects is made even more difficult when one considers how PM can vary in space and time as a consequence of atmospheric chemistry and weather conditions. In addition, complex interactions exist between PM and gaseous air pollutants (such as ozone and nitrogen dioxide), and these gaseous pollutants share biologically plausible associations with various health endpoints that are also potentially related to PM (Kelly, 2003). Indeed, some of the strongest epidemiological evidence on associations between PM and mortality and morbidity highlights the complexities of disentangling effects of specific components of these pollutant mixtures (Krewski et al., 2000; Gauderman et al., 2004).

References

Gauderman, W.J., Avol, E., Gilliland, F., Vora, H., Thomas, D., Berhane, K., McConnell, R., Kuenzli, N., Lurmann, F., Rappaport, E., Margolis, H., Bates, D., Peters, J., 2004. The effect of air pollution on lung development from 10 to 18 years of age. New England Journal of Medicine 351, 1057e1067.

Kelly, F., 2003. Oxidative stress: its role in air pollution and adverse health effects. Occupational and Environmental Medicine 60, 612e616.

Krewski, D., Burnett, R.T., Goldberg, M.S., Hoover, K., Siemiatycki, J., Abrahamowicz, M., White, W.H., 2000. Reanalysis of the Harvard Six Cities Study and the American Cancer Society Study of Particulate Air Pollution and Mortality. Health Effects Institute, Boston.

Vivaldo G, Masi E, Taiti C, Caldarelli G, & Mancuso S. The network of plants volatile organic compounds Scientific Reports 7: 11050 2017 DOI:10.1038/s41598-017-10975-

WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide. Global update 2005. ISBN 92 890 21926.

BTS v1 Sep 2019