Science for Environment Policy

Cell studies provide insights into toxic effects of particulate matter

A mixture of fine particles in air leads to harmful effects on human health. Currently, particulate matter (PM) is defined in policy by particle size, but according to a new study, focusing on air pollutants and their toxic effects on cells may provide an effective way to legislate for PM.

In air quality legislation, PM is divided into two size categories irrespective of chemical composition. $PM_{2.5}$ is the smaller fraction, including particles less than 2.5 micrometres (µm), and PM_{10} includes particles up to 10 µm. The directive on ambient air quality and cleaner air for Europe (2008/50/EC) [1] requires EU Member States to reduce average annual $PM_{2.5}$ concentrations and, in 2015, the annual limit of 25 µg/m^3 will become mandatory.

The researchers were concerned with the very specific biological effects that different components of $PM_{2.5}$ can cause. Between 2005-2006, they collected $PM_{2.5}$ samples at sites in Cork, Ireland, and tested their effects on human lung cells grown in a laboratory. As legislation is often targeted at urban environments, they compared samples from city centre and rural locations to understand whether this urban focus is justified.

The researchers showed that the chemical composition of samples varied across the different sites and between seasons. Compared to rural samples collected 10km away from the city centre, those collected in the city centre and another site 3km outside the city centre contained higher levels of metals, including copper and manganese, produced by human activities, such as vehicle emissions, galvanising and oil combustion.

Further experiments focused on three main types of biological effects on lung cells: cell damage and death (cytotoxicity), production of inflammatory molecules called cytokines, and production of reactive oxygen species (ROS), which are known to damage cells. Summer PM samples collected from all sites caused the most cell membrane damage in cytotoxicity experiments, and were most potent in stimulating cytokine production. For example, one particular type of cytokine (IL-6) was released in significantly higher quantities when cells were exposed to the summer samples compared to those collected at other times of the year. Spring samples from the city centre also caused significantly higher IL-6 release compared to spring samples from the other two sites. However, for another type of cytokine the quantities released were not significantly higher than those released in control cells.

One of the main findings was that, whilst all samples caused cells to produce ROS, samples from the city centre and from the site 3km away, which were characterised by elements from combustion sources, had a greater capacity for inducing ROS production. When the researchers carried out statistical analysis on the strength of the association between location and the different biological effects, ROS production was the most obviously related to location.

According to the researchers, the two more centrally located sites did not exceed the new 25 µg/m^3 limit value at any point during the study. Therefore, the effects demonstrated on cells all occurred within legal limits for $PM_{2.5}$ that will become effective in 2015. Current PM_{10} limits were only exceeded once. The researchers believe focusing on specific chemicals could be a cost-effective way to legislate for PM and recommend that other indicators of toxic effects, such as stress due to ROS, are explored further.

One limitation of these types of studies is that they involve a large number of variables, creating uncertainties that make it difficult to reach statistically significant conclusions. In addition, the study did not take into account organic components that might also contribute to toxic effects.

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