URBAN air pollution: a new look at an old problem

Large urban agglomerations inevitably lead to air pollution. But despite the significant impacts on human health and climate, we lack systematic measurements of air pollution in many cities. **Megan L Melamed**, **Tong Zhu** and **Liisa Jalkanen** discuss a new global assessment that illuminates the knowns and unknowns.

London has been intimately familiar with air pollution since medieval times, but the winter of 1952 nevertheless came as a rude shock: the city was blanketed by smog that persisted for four days. Known as "The Great Smog", this event is estimated to have caused 4000 premature deaths. Los Angeles too had encountered severe smog in the 1940s. These events served as wake-up calls, prompting the US and UK governments to enact legislation and set air-quality standards in the 1950s. As a result, today's residents of London and Los Angeles breathe much easier.

Those residing in other cities aren't so lucky. Two recent media articles highlighted the air pollution in Beijing and Salt Lake City, two cities on opposite sides of the world. In both cities, the combination of emissions and weather conditions leads to smog. And despite the advances made by London and Los Angeles, the concentrations of particulate matter in these cities remain higher than the limits set by the World Health Organization (WHO; Figure 1).

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Air pollution is clearly a pernicious problem and its health impacts are set to worsen as several regions of the world urbanise rapidly. A recent report by the Organisation for Economic Co-operation and Development (OECD) says that by the year 2050, outdoor air pollution is projected to be the world's top environmental cause of mortality, ahead of dirty water and lack of sanitation (OECD 2012). But human health is just one dimension of air pollution. Unclean air also affects crop growth and reduces the productivity of agriculture (for example, Shindell *et al.* 2012). It affects climate in a complex manner. Understanding the types and spatio-temporal patterns of urban air pollution is crucial to exploring its implications for human and ecosystem health, food security and climate.

In September 2012, the World Meteorological Organization and IGBP's International Global Atmospheric Chemistry (IGAC) project published the first international assessment of available information on air pollution in major urban agglomerations. The report entitled *The Impact of Megacities on Air Pollution and Climate* examined data from Africa, Asia, South America, North America and Europe. It concluded: (1) air pollution continues to be a serious problem across the world; (2) the amount of scientific knowledge varies greatly between megacities; (3) there is a clear opportunity to translate knowledge from well researched urban areas to less researched urban areas to mitigate air pollution; and (4) large urban agglomerations may be the best places to realise the co-benefits of simultaneously controlling air pollution and mitigating climate change.

Assessing and improving air quality

Air pollution typically refers to a set of common substances – also

Air pollution is a challenge in cities such as Jakarta, pictured here.

known as criteria pollutants – that have demonstrable impacts on human health and ecosystems. The main culprits are lead (Pb), carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3) and particulate matter (PM). Particulate matter in the form of soot and other small particles floating in the air is usually classed as $PM_{2.5}$ (particles with diameters smaller than 2.5 micrometres) or PM_{10} (particles with diametres less than 10 micrometres). Both affect human health as well as climate. We can see from Figure 1 that across 26 cities, despite large differences in PM_{10} concentrations, even the most developed cities approach or exceed WHO air-quality guidelines.

WHO estimates that air pollution causes more than 2 million premature deaths each year (WHO 2006). In 1987, WHO published *Air Quality Guidelines for Europe*. In 2005, following important new research from low- and middle-income countries, it released new *Air Quality Guidelines* for four common pollutants (PM, O_3, NO_2, and SO_2) that are intended to inform policymakers on appropriate targets related to air-quality management (Table 1; WHO 2006).

Table 1: WHO air quality guidelines, 2006.

Pollutant	Concentration	Averaging Period
Particulate matter ($PM_{2.5}$)	10 μg/m³ 25 μg/m³	1 year 24 hour
Particulate matter (PM_{10})	20 μg/m³ 50 μg/m³	1 year 24 hour
Ozone	100 μg/m³	8 hour
Nitrogen dioxide	40 μg/m³ 200 μg/m³	1 year 1 hour
Sulphur dioxide	20 μg/m³ 500 μg/m³	24 hour 10 minute

Could newer cities learn from the experience of older cities?

The implementation of air-pollution control strategies typically occurs at the level of cities rather than at a national or international level. Each city is different. The local meteorology varies and pollutants can sweep in from long distances – even trans-continental – affecting ambient air quality. In addition, the geographic, economic, political and social contexts vary greatly across the world. Thus, air-quality control programmes will likely vary in their approach to air pollution. Policymakers and politicians must balance health risks, technological feasibility, economic considerations and various other political and social factors.

Major international events have often helped draw attention to air-quality issues and attract international research efforts. For example, in the run-up to the 2008 Beijing Olympics an international collaborative research project, Campaigns of Air Quality Research in Beijing and Surrounding Regions (CAREBEIJING), was implemented. The project was designed to study the regional air pollution processes that affect air quality in Beijing and to formulate air-pollution control strategies for the Olympics. When considered on an average annual basis, the air quality in Beijing has certainly improved although the recent smog suggests that there is some distance to travel.

Ultimately, however, the old adage "You can't manage what you can't measure" applies here. Successful implementation and enforcement of air-quality measures is dependent on access to scientific information. The megacities assessment clearly shows the disparity in scientific knowledge across large cities. Cities that have had access to high-quality information – Los Angeles, for example – have benefited. Could newer cities learn from the experience of older cities to avoid teething troubles?

Experience shows that this can indeed be the case. A prime example is shown in Figure 2, which shows how ozone and PM levels changed through time in three similarly sized megacities:

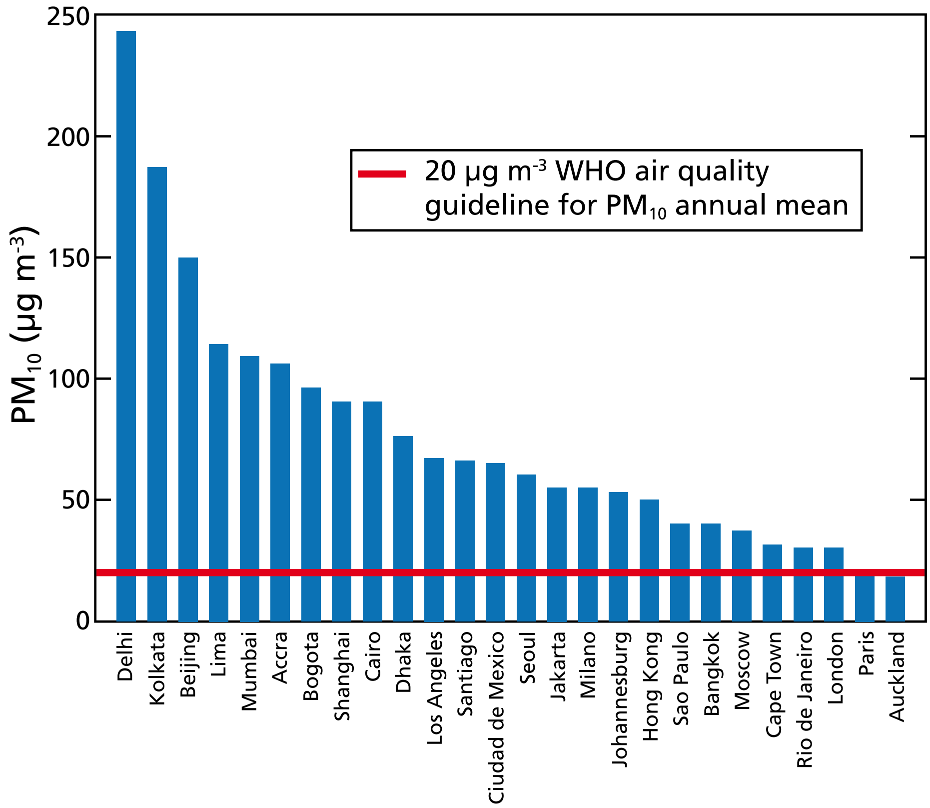

Figure 1. Comparison of annual mean concentration of PM_{10} across urban areas (Zhu *et al.* 2012).

Los Angeles, Mexico City and Beijing. During the time period depicted in the figure, each city had a population within ± 40% of the average of the three cities. In Los Angeles, ozone concentrations peaked in the early 1970s and have been decreasing over the past four decades. We can see that the ozone levels in Mexico City never reached the peaks of Los Angeles and levels fell faster. Today, the ozone and PM concentrations in Los Angeles and Mexico City are nearly the same. Mexico City avoided severe air pollution by translating the lessons of Los Angeles to implement emission controls.

Beijing, however, seems to be on a different track. PM concentrations remain higher than the two other cities but are decreasing. In contrast, ozone concentrations, which have been low, are rising. As mentioned earlier, Beijing has taken numerous measures during the past few years to control air pollution. Assessing how these measures are working will not only help Beijing to fine-tune its policies but will also hold lessons for more recently urbanising centres.

An integrated approach

Although the impact of big cities on local air quality has long been recognised, the impacts on regional and global climate are beginning to receive increased attention. We know now that air pollutants can drive climate change in complex ways (see Arneth *et al.* 2009, for example). Many pollutants (such as sulphur dioxide) form tiny droplets that deflect incoming solar radiation and tend to cool the climate. Pollution control policies that reduce the atmospheric concentrations of such substances can in fact lead to warming. Other pollutants – black carbon (soot) in particular – can absorb incoming solar radiation and lead to warming. Because black carbon is also a significant health hazard, policies aimed at controlling the emissions of this substance could lead to a win-win scenario (see page 9 of this issue).

With this emerging understanding, there is little justification for keeping air pollution and climate change in separate boxes. These are issues with overlapping temporal and spatial scales and should be addressed in an integrated manner. It has been argued that megacities and other large urban agglomerations are the best places to realise the co-benefits of simultaneously controlling air pollution and tackling climate change.

The *WMO/IGAC Impacts of Megacities on Air Pollution and Climate* assessment sought to evaluate the current state of knowledge and identify gaps. It reveals that the quality and quantity of available information is highly variable, with air pollution in some cities being much better characterised than that in others. The gaps underscore the need for continued international efforts to measure urban air quality and use this information to improve air quality while simultaneously mitigating climate change.

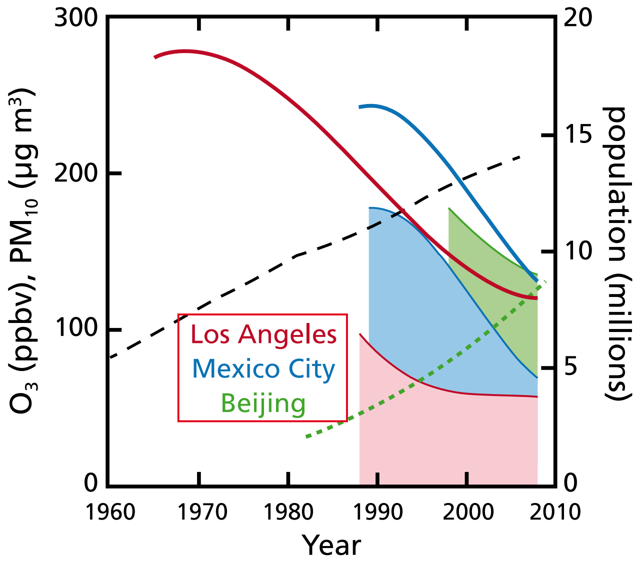

Figure 2. Comparison of the evolution of ambient ozone (solid and dotted thick lines) and PM_{10} (thin lines shaded to zero) concentrations in three megacities of similar populations. The black dashed line shows the trend of the average population of the three cities. (Zhu *et al.* 2012).

We know now that air pollutants can drive climate change in complex ways.

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