



## Why particles?

### 1. Introduction

Particles are both the oldest and newest of air pollutants. Being visible to normal human sight in the form of airborne smoke and as dirt on surfaces, they figured early in public perceptions of urban air quality (Lodge et al., 1969). Due primarily to the use of solid fuels, severe particle pollution conditions existed in the past in many cities throughout the world (Markham, 1994). Indeed, bringing them under control in large cities of the currently developed world in some cases took three-quarters of a millennium (Brimblecombe, 1987). They were thus the first pollutant category to be widely monitored, initially in the form of deposited soot (Anonymous, 1912), and later as mass or simple optical measures of total particle levels collected on filters (Shaw and Owens, 1925; Meetham, 1964).

Starting in the mid-20th century, a large set of urban epidemiological studies, mostly of several-day high-pollutant episodes in the UK and the US, established the scientific basis used for widespread promulgation of ambient standards in developed countries, first in the 1950s, and then, more widely, in the 1970s (Grant et al., 1999). Relying on the same evidence, the 1979 World Health Organization Air Quality Guidelines (World Health Organization and United Nations Environment Programme, 1979) in turn were used by many other countries around the world as the basis for their own standards.

These standards were based on evaluations of the health effects that indicated a possible threshold, i.e., a level below which no health effect could be expected. Fig. 1, for example, reproduces a figure from one of the principal scientific evaluations used to set standards in the 1970s (US National Research Council. Committee on Particulate Control Technology, 1979). It shows a clear “no effects” level for particle concentrations (in association with SO<sub>2</sub>). Although not without important dissenters at the time (Lave et al., 1977), finding and accepting a no effects level was (and is) quite attractive as a method to set standards and guidelines.

Although by no means considered to be completely resolved, in the period after the late 1970s particle air

pollution did not garner principal attention in air pollution policy debates, which focused on photochemical agents, toxic pollutants, and other issues. In the mid-1980s both the US (US Environmental Protection Agency (US EPA), 1987) and WHO-Europe (World Health Organization. Regional Office for Europe, 1987) adjusted standards and guidelines to focus on smaller size fractions (PM<sub>10</sub>), but the accepted basic structure of impacts remained intact.

Starting in the 1980s and accelerating in the 1990s, however, three semi-independent sets of developments have caused a second boom in the attention garnered by particle air pollution around the world:

- Although particle levels in developed-country cities improved dramatically in the second half of the 20th century, it is now clear that
  - Outdoor particle levels in many developing-country cities have reached levels that rival the worst found in the old days of developed-country cities (World Health Organization (WHO), 1999a). For comparison, Fig. 2a and b illustrate the distribution of current particle levels, in the form of PM<sub>10</sub>, in Indian and US cities. Note that the worst US metropolitan area is cleaner than the best ambient monitoring station in urban India.
  - Because of the household use of solid fuels for cooking and heating in developing countries, a third or more of the world's population is exposed to even higher levels indoors (Smith, 1993). Fig. 2c shows the particle distribution measured in Indian solid-fuel using households, for comparison to the urban values. These extend the concentrations, as well as the population, well beyond what is found in developing-country cities.
- A large number of epidemiological studies have been published, some based on reanalysis of older results and some on new datasets, have greatly improved the ability to estimate health effects from particle air pollution:
  - Importantly, these studies have shown effects (Holgate et al., 1999):

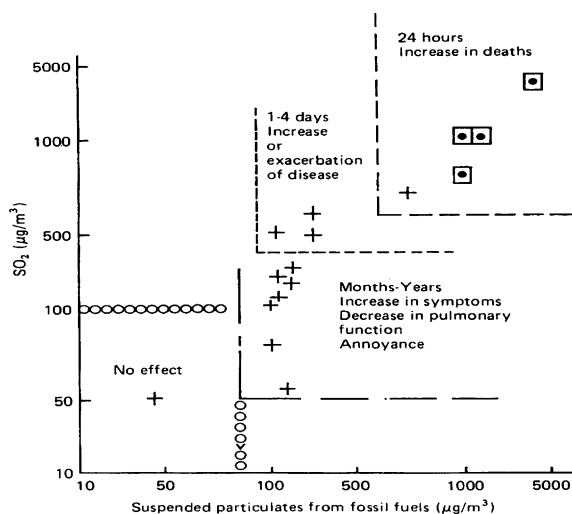


Fig. 1. Exposure–response graph from USNRC/USNAS-1979.

- at concentration levels previously thought to be benign;
  - that emphasize the importance of even smaller size fractions; and
  - show no apparent thresholds at lower concentrations.
- As a result of these studies, important changes in standards and guidelines were initiated on both sides of the North Atlantic:
    - The US Environmental Protection Agency proposed ambient standards for  $PM_{2.5}$ , although retaining those for  $PM_{10}$  (US Environmental Protection Agency (US EPA), 1996).<sup>1</sup>
    - The World Health Organization adopted a revised set of Global Air Quality Guidelines for  $PM_{10}$  that, in sharp contrast to previous guidelines, do not specify actual concentrations but are in the form of graphs representing exposure–response slopes with no thresholds (World Health Organization (WHO), 1999b).<sup>2</sup> Fig. 3 reproduces the  $PM_{10}$  guidelines for mortality for illustration.<sup>3</sup> Setting standards using such tables will be a much

<sup>1</sup> As of this writing, implementation of these standards is pending outcome of court cases.

<sup>2</sup> These global guidelines were adapted with little change from the provisional WHO-Euro guidelines, which, however, to date have yet to be officially adopted (World Health Organization. Regional Office for Europe, 1997).

<sup>3</sup> The Global Air Quality Guidelines specify that the exposure–response relationships are not to be applied to indoor particle levels, but that the older WHO-Euro guidelines (World Health Organization. Regional Office for Europe, 1987) could be used for this purpose.

greater challenge for many governments than using guidelines based on thresholds (Lippmann and Maynard, 1999).

- Since 1980, there has been increasing attention to the importance of exposure assessment in the evaluation and control of airborne and other health-damaging pollutants (US National Research Council. Board on Environmental Studies and Toxicology. Committee on Advances in Assessing Human Exposure to Airborne Pollutants, 1991). There are a number of aspects of this shift in worldview:
  - In addition to advances in methods and technology at the level of individual exposure assessment, during this period receptor–source modeling has been developed and widely used in developed countries (Watson, J.G., Air and Waste Management Association, TP-5 Receptor/Source Apportionment Committee, 1989; Hopke, 1991). Such modeling approaches are powerful tools for determining the link of exposure at a particular place to particular sources.
  - Because particles have many sources and sinks, in association with their different sizes and compositions, there is great challenge involved, inter alia, in determining the relationship between traditional ambient monitoring results and relevant human exposures (Wallace, 2000).
  - Because an exposure perspective reveals quite different relationships between particle sources and ill-health than does one based on ambient monitoring, there are important gains possible in focusing policy on exposure rather than ambient concentrations (Roumasset and Smith, 1990; Smith, 1995).

Application of the more robust exposure–response data now available to ambient measurements indicate that ambient particle levels still impose a substantial risk of premature mortality in developed countries by comparison to other risks affecting such societies. Several tens of thousands of annual premature deaths can be associated with particle concentrations in the US (Shprentz et al., 1996) and levels approaching ten thousand are estimated for the UK (Holgate, 1998), for example. Using the available particle epidemiology, which was developed with different populations and exposure levels, several hundreds of thousands of annual premature deaths can be associated with ambient levels globally (Schwela, 1996; Working Group on Public Health and Fossil Fuels, 1997) with totals of more than two million when indoor particle sources are included (World Health Organization (WHO), 1997).

In parallel to these developments in air pollution science, the health community in the 1990s has been developing and applying new concepts and approaches to policy assessment. Prominent among these is the

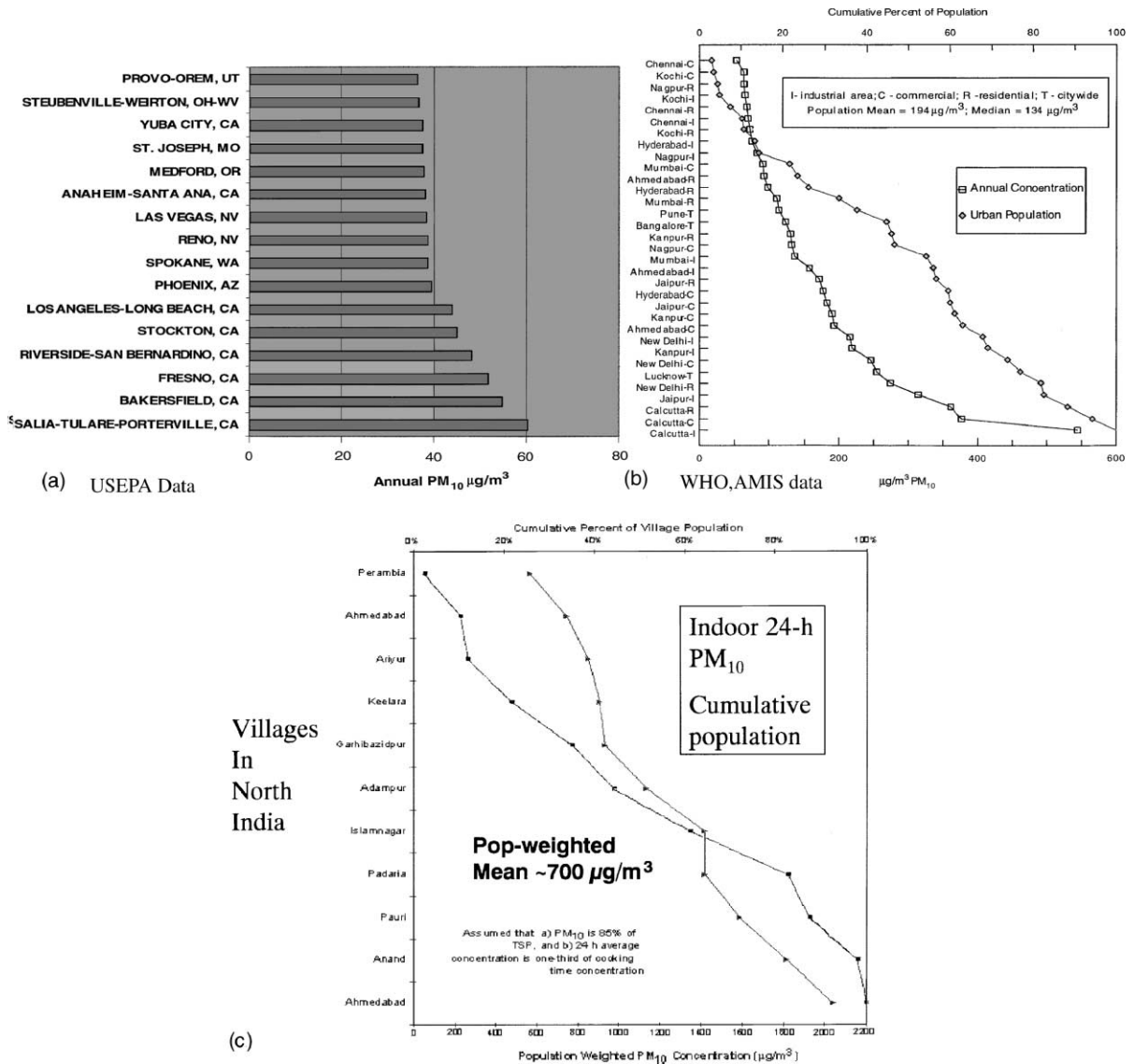


Fig. 2. (a) Worst 20 urban areas in US: PM<sub>10</sub> in early 1990s, (b) urban PM<sub>10</sub> in India, (c) indoor air pollution in India (Smith, 2000).

burden of disease approach, which allows for combining deaths, illness, and injuries across all population groups (age and sex) into a single metric of lost healthy life years, a much more useful measure than simple premature mortality (Murray and Lopez, 1996). On this basis, a preliminary analysis indicates that ambient particle exposures globally account for about 0.5% of the global burden of disease, mostly in developing countries where urban levels are high (Hong, 1995; Murray and Lopez, 1996). Recent preliminary analysis of the burden from solid fuel use in developing countries, which seems to be best indicated by indoor particle exposures, places its

burden at about 4% of the global total, with the bulk of the burden falling on young children (Smith, 2000).<sup>4</sup>

Although imperfect, the burden of disease calculations indicate that particle air pollution remains a global risk factor of substantial proportions. At 4-5% of the

<sup>4</sup> The WHO Global Programme on Evidence for Health Policy has contracted for revisions and updates of these burden of disease estimates for indoor and outdoor air pollution, as well as other major risk factors, to be published in the World Health Report, 2002, of the World Health Organisation, Geneva.

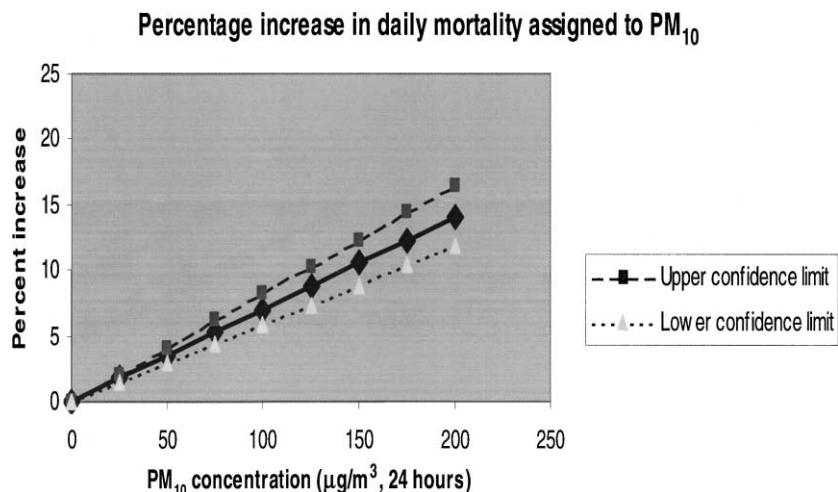


Fig. 3. Sample exposure–response graph from WHO air quality guidelines-1999.

global burden in the early-1990s, it stood well above estimates of the burden from vehicle accidents, alcohol abuse, hypertension, unsafe sex, and tobacco, and was exceeded only by malnutrition and poor water/hygiene/sanitation. Compared to the burden of specific diseases, it exceeded the total of all (ischaemic) heart disease and was roughly equal to the total for all cancer. In more refined estimates being prepared for 2000, tobacco and unsafe sex, which have been rising rapidly, will also exceed the burden from particle air pollution, but still leave it approximately fifth among the major avoidable risk factors in the world (Murray et al., in press).

There are a number of important classes of uncertainty in these global estimates (Smith, 2000). Here two bear special attention:

- Although particle levels seem to be closely related to health effects, they generally appear in association with other pollutants and it is not clear that they are always the primary direct cause of the ill-health and not just an indicator of the effect of the mixture. Thus, there is need to better differentiate types of particles so as to assist in identifying the actual culprits and how they can be best controlled.
- The quality, quantity, scale, and extent of monitoring for particle levels is to date almost inversely related to where particle exposures seem greatest, i.e., we are fairly certain about levels experience by those living in the most particle-free environments, such as North American and European cities, and least certain about levels in the dirtiest environments, such as the cities and households of the developing world (Smith, 1993). Thus, there is a need to find techniques and resources to deploy monitoring efforts in a different manner than has been done in the past.

The remaining importance of particle pollution in developed countries, the high levels in developing countries, and the apparent scale of its impact on the global burden of disease underline the importance of particles as an environmental health risk and the consequent need for monitoring. In addition, however, to address the important uncertainties outlined above, such measurements need both to be more differentiated than has been typical in the past and to be done in different places.

The set of papers in this special issue (SGOMSEC-14) thus address the methodology for more differentiated measurements of this oldest of pollutants. Overview papers address measurement and modeling techniques for particle emissions, concentrations, and exposures. In addition, however, the papers reflect on how these techniques might be applied in developing-country settings, where particle levels are highest but available resources are limited. Individual papers address specific sub-topics within these arenas.<sup>5</sup>

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<sup>5</sup> Because of the growing concern about the impact of human-generated air pollution on global change, with resulting impacts on human welfare, a paper related to particle impacts on global atmospheric processes is also included. Such concerns impose still different requirements on the methods and locations of particle measurements.

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