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EDITORIAL

Particulate matter, science and EU policy

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Several new research findings regarding the health effects of airborne particulate matter (PM) (usually studied by the size of the particles, *e.g.* PM10, particles with a 50% cut-off aerodynamic diameter of 10 μm, and PM2.5, particles with a 50% cut-off aerodynamic diameter of 2.5 μm) have been presented at two important scientific meetings held in September 2006: the Conference of the European Respiratory Society (ERS), in Munich, and the joint Conference of the International Society for Environmental Epidemiology (ISEE) and the International Society for Exposure Analysis (ISEA) in Paris. This is not surprising, since: 1) the health effects of air pollution are among the largest environmental problems worldwide [1]; 2) several scientific questions are still open; and 3) common research efforts from the epidemiological, toxicological and clinical worlds are under way.

SCIENTIFIC EVIDENCE

A brief review of the evidence follows. The initial suggestion that mortality increases due to long-term, low-level exposure to PM was provided by the Harvard Six Cities study [2]. These findings were confirmed in the long-term follow-up (1982–1998) of the American Cancer Society (ACS) II cohort, consisting of ~500,000 adults from metropolitan areas throughout the USA [3, 4]. In the latter study, each 10 $\mu g \cdot m^{-3}$ elevation in PM2.5 was associated with approximately a 6, 9 and 14% increased risk of all-cause, cardiopulmonary and lung cancer mortality, respectively. A recent report from Los Angeles [5], which included a large proportion of the ACS II cohort from that area, has indicated that a more refined method for assessing exposure produces a higher risk estimate of mortality increase (17% increase; 95% confidence interval 5–30%) for an increase of 10 $\mu g \cdot m^{-3}$ in PM2.5. Well-conducted cohort studies in Europe, which have estimated air pollution exposure at individual residences, confirm the findings from the USA and indicate that air pollution emitted from road traffic, including PM, is of greatest concern [6–8]. The evidence of chronic effects has also accumulated for morbidity data, which indicate that the respiratory effects of long-term exposure include a decrease in lung function and signs of atherosclerosis progression [9–12]. Mortality cohort studies from Europe have not yet been able to study PM2.5 directly but European Union (EU)-funded studies have demonstrated that the correlation between PM2.5 and pollutants shown to be associated with mortality is high [13].

Scientific evidence of the health effects of particulate air pollution is not limited to studies of long-term exposure. In several cities throughout the world, consistent associations have emerged between daily mortality and ambient concentration of PM during the same or the previous few days. The results of two collaborative projects conducted in 90 cities in the USA (National Morbidity Mortality Air Pollution Study; NMMAPS) and in 29 cities in Europe (Air Pollution Health Effects Approach; APHEA-II) have been reported. In the American cities, where annual average concentrations of PM10 ranged 23–46 $\mu g \cdot m^{-3}$, a 0.27% increase in total mortality and a 0.69% increase in cardiorespiratory mortality were detected for a 10 $\mu g \cdot m^{-3}$ increase in PM10 [14]. There was no evidence of a threshold and the effects were linear even at low levels of concentration. In the European study, based on the most extensive database available in Europe and covering a large range of PM10 concentrations, the risk estimate for overall mortality was 0.6% per increase of 10 $\mu g \cdot m^{-3}$ in PM10 [15] and was 0.76% per 10 $\mu g \cdot m^{-3}$ PM10 for cardiovascular mortality [16]. Also in Europe, large national studies are available from Spain [17], the Netherlands [18], France [19] and Italy [20] showing similar results.

Short-term effects on respiratory diseases have been detected in both children and adults [21]. However, recent evidence has indicated that the effects on the cardiovascular system are of key importance and that the involvement of the heart may be particularly important in the risk of death associated with air pollution among chronic obstructive pulmonary disease (COPD) patients. Recent studies have shown that sudden cardiac death and myocardial infarction could be triggered by particulate air pollution in the general population [22–24] and among people who have already suffered a myocardial infarction [25].

Thus, the science regarding the health effects of PM is evolving rapidly. A comprehensive and detailed review was published in June 2006 [26] and, quite recently, more papers appeared on the subject of long-term respiratory effects among children [27, 28], adult mortality [29], myocardial infarction [30] and COPD [31]. In addition, research on short-term effects is progressing, with indication of an effect on heart failure [32], arrhythmia [33] and stroke [34], together with evidence of socioeconomic differences in PM-related mortality [35].

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Experimental research into the understanding of the mechanisms that underlie the observed effects of PM and other pollutants has also rapidly progressed in recent years. While details of the pathophysiological mechanisms remain to be elucidated, numerous experimental models confirm that PM and other oxidant pollutants interfere with a range of mechanisms that are relevant for the observed pathologies. In particular, oxidative stress and inflammatory responses in the respiratory system along with consecutive systemic inflammatory responses have been described in several studies. Moreover, endothelial dysfunction, oxidation of lipids, vascular inflammation, induction of a pro-thrombotic state, as well as interactions with the autonomic function, may explain in particular the various cardiovascular effects associated with ambient air pollution and that the established oxidative and genotoxic effects of PM (particularly PM from diesel engines) are in line with observed associations between air pollution and lung cancer rates [36].

Finally, evidence is accumulating on the most critical issue: are there benefits of exposure reduction? Studies in Dublin, Ireland [37], Switzerland [38] and Germany [39, 40] show that reductions in air pollution and PM are clearly associated with a reduction in health effects. A recent report from the USA indicated that mortality from natural causes decreased following reductions in $PM_{2.5}$ concentration; these observations came from the Harvard Six Cities study that originally suggested the chronic effects of air pollution [41]. In the 11 countries that collaborate within the European APHEIS Network [42], a reduction to a yearly average concentration of $PM_{2.5}$ of 15 $\mu g \cdot m^{-3}$ would result in life expectancy gains, at age 30 yrs, of 1 month to >2 yrs [43]. At the EU level, with its 450 million inhabitants, the stakes are even greater. The benefits of more stringent PM standards to both general and susceptible populations would be large [44]. Although implementing more stringent air pollution legislation requires more resources, detailed cost-benefit calculations commissioned by the EU have shown that health benefits gained from reduction of $PM_{2.5}$ in Europe clearly outweigh these costs.

IGNORANCE OF EVIDENCE

Because scientific results provide such clear messages on the dangers of PM and the benefits of reducing exposure, it is natural to believe that public health measures should be adopted in order to achieve adequate protection of the exposed population. The recent document updating the World Health Organization (WHO) Air Quality Guidelines [1] provides strong scientific support for policy and a general framework to promulgate air pollution standards in both the developed and underdeveloped world. The long-term air quality guideline for $PM_{2.5}$ has been set to 10 $\mu g \cdot m^{-3}$.

Unfortunately, the interplay between science, public health needs and actual policy measures is not without difficulties. Europe is facing a transition regarding legislation on air pollution and PM. Several European scientists have publicly expressed their concerns regarding some measures foreseen by the proposed EU directive on air quality, published on September 21, 2005 [45]. In addition, the ERS has released a position paper regarding the drafted new directive [45] with concerns about the proposed limit value for $PM_{2.5}$ and about the proposed changes to already existing regulations regarding PM_{10}. Briefly, the main concerns are as follows.

1) Neither the proposed $PM_{2.5}$ ''cap'' annual average of 25 $\mu g \cdot m^{-3}$ nor the target value proposed by the EU Parliament on September 26, 2006 (20 $\mu g \cdot m^{-3}$) are sufficient to adequately protect public health. The proposed directive recognises the importance of fine particulate matter and that major adverse effects on health occur in Europe today as a consequence of current exposure to $PM_{2.5}$. The proposed directive indicates that over the next 15 yrs, all EU member states should reduce their $PM_{2.5}$ concentrations by $\geqslant$20% unless their average level is <7 $\mu g \cdot m^{-3}$. However, the ''exposure reduction'' plans in the proposed directive will not be legally binding. The target value being proposed is a cap of an annual average $PM_{2.5}$ concentration of $\mu g \cdot m^{-3}$ in 2015 (EU Parliament). This level has been associated with very significant adverse health effects, as documented by studies conducted in Europe and elsewhere. The concern is that the net effect of this directive will be that most member states will no longer be stimulated to take exposure reduction measures, as they are already at or below the 20–25 $\mu g \cdot m^{-3}$ cap. The legally binding annual mean standard in the USA and California is set at 15 and 12 $\mu g \cdot m^{-3}$, respectively.

2) The exclusion of all ''natural'' PM from compliance considerations in effect reduces the public health protection from PM_{10}. The European Commission proposes to allow member states to subtract all natural PM from compliance considerations. However, the existing limit values for PM_{10} (according to the 1999 EU directive [46]) are based on scientific findings regarding the exposure-response relationships of the health effects of particles in ambient air. These relationships have always included the ''natural background'' as it reflects the real, health-damaging concentrations affecting people. Conversely, the scientific evidence is not reassuring about the short-term health effects of coarse particles on the respiratory system [47]. This new proposal would allow for higher PM_{10} values than expressed in the existing legislation and therefore weaken health protection.

3) New derogations for PM_{10} attainment values reduce the public health protection from PM_{10}. The European Commission's proposal introduces new derogation possibilities that would allow member states to delay reaching the legally binding limit values by up to 5 yrs. This would apply to the limit values that already entered into force in 2005 (for PM_{10} levels) as well as to the limit values which are to enter into force in 2010 ($PM_{2.5}$). In line with this weakening of proposals, the EU Parliament adopted an annual limit value of 33 $\mu g \cdot m^{-3}$ from 2010 (1999 EU directive: 20 $\mu g \cdot m^{-3}$ as of 2010 [46]), with the unfortunate amendment to allow countries exceedance of the daily limits (50 $\mu g \cdot m^{-3}$) on 55 $days \cdot yr^{-1}$ (7 $days \cdot yr^{-1}$ from 2010, according to the 1999 EU directive [46]). The current authors acknowledge that in the real world the limit values may be hard to reach in the short term in some areas in Europe. However, it seems likely that weakening the already agreed and adopted air quality legislation will contribute to an erosion of the credibility of the EU in firm implementation of legislation.

In conclusion, the proposed directive does not adequately reflect the best scientific evidence. In the face of the extensive evidence regarding the effects of particulate matter on health, the American Thoracic Society and other health organisations

have also recommended promulgation of National Ambient Air Quality Standards (NAAQS) for particulate matter which protect public health with ''an adequate margin of safety'' [48]. If the proposed directive is approved in its present form, a reduction of the health impacts of air pollution in Europe will be unattainable.

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