

**FINE PARTICLES: FROM SCIENTIFIC UNCERTAINTY TO POLICY STRATEGY**Rob Maas<sup>1</sup>**ABSTRACT**

*Gaps in our knowledge should not be a reason for not making policy decisions. How can we define robust policy strategies given the various uncertainties in the sources, exposure and causes of health effects? Which uncertainties are most important? What are its policy implications? This contribution will describe policy strategies for particulate matter (PM) abatement that are consistent with certain sets of assumptions, as well as the risks that are associated with such strategies. What is an optimal strategy assuming that the fine particles (PM<sub>2.5</sub>) are the main cause of health effects? And what would be the 'mistake' of such a strategy, if 'in the end' PM<sub>10</sub> or carbonaceous particles prove to be the 'real' cause? How can we make the policy strategy more robust and minimise its financial risks and health risks. The contribution will describe a systematic way of dealing with the knowledge gaps in the policy process.*

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## UNCERTAINTY AND INCERTITUDE

Within the source-effect chain of particulate matter one can find large uncertainties almost everywhere. Emission data are not very reliable, if compared with for instance SO<sub>2</sub> or CO<sub>2</sub>. Emission data for PM<sub>10</sub> and PM<sub>2.5</sub> seem to be incomplete. Currently we can only partly explain the background concentrations from these primary emissions and from the production of secondary particles in the atmosphere. Anthropogenic PM-emissions might be underestimated, e.g. the emissions from wood burning, from the aberration of tires and brakes, or the re-suspension of particles. Moreover, a substantial amount of the primary and secondary natural emissions are not taken into account (such as Sahara dust and biogenic organic particles), and the transcontinental influx might be underestimated. We can explain the formation of secondary inorganic particles from SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> emissions relatively well, but our understanding of the secondary organic particles is still poor. We also know little about the water-content of particles. Furthermore, large scale models can only partly estimate the actual exposure of the population in the streets and in buildings.

All the uncertainties mentioned above seem to be mainly caused by the lack of (reliable) data and can basically be solved by better measurements. With statistical techniques (such as error propagation) we can estimate the likelihood that an abatement measure will reduce human exposure based on our estimates of the uncertainty margins in the input data.

However the biggest challenge in the PM-case is our lack in knowledge about the fraction that is really causing the problem. Or is it too much knowledge, because there are several 'competing' theories to frame the problem? This incertitude cannot be treated in the same way as the uncertainties mentioned above (Hissemöller and Hoppe, 1996; Van der Sluijs et al, 2003; Maas 2003). We cannot attach a probability to either one of the other theories. And as long as one of these theories is not falsified, there remains a fair chance that such a theory might be correct. The real challenge in the PM-debate is to acknowledge that there is not just one best theory, but that there are several ways to describe 'reality' and to deal with this incertitude in the policy process.

## CHANGING REALITIES

If we look back and see how the science has developed over the past decade, we can conclude that some modesty about our current knowledge is appropriate. In the 1950s we thought that Black Smoke was causing lung diseases and we reduced its emissions by over 80%. In the 1970s it was sulphur, which by now is also reduced by more than 80%. In the 1990s PM<sub>10</sub> was identified as the cause. Current policies aim at a reduction of PM<sub>10</sub> by more than 80% in the EU. But still if we look at health indicators like lung cancer and prevalence of Chronic Obstructive Pulmonary Disease (COPD) we do not see much change. Other determinants like 'lifestyle' seem to be more dominant than air pollution (Murray and Lopez, 1996). In the past decades in the Netherlands, for example, lung cancer and COPD per 1000 women increased due to an increase in smoking (National Compass Public Health, 2005). A much closer look into the available epidemiological data is required to detect an association between PM-exposure and health. Currently - based on American studies (e.g. Pope et al. 2002) - the association between PM<sub>2.5</sub> exposure and health seems to be stronger than between PM<sub>10</sub> and health, and although an effect of PM<sub>10</sub> is not completely ruled out, PM<sub>2.5</sub> seems to replace PM<sub>10</sub> as the focus of the policy makers' attention (Melcher et al, 2002). In Europe this finding is not yet confirmed. PM<sub>2.5</sub> and PM<sub>10</sub> are part of the conventional theory, although toxicological explanations behind its damaging effects are hypothetical (Buringh and Opperhuizen, 2002a, b).

Relatively little epidemiological research funds are focused on the alternative views that for instance specific PM-compounds such as carbonaceous particles (organic carbon, elementary carbon, PAH) could be causing the problem (WHO 2004; Kameda et al., 2005), or certain heavy metals, or the ultrafine particles. Incidentally for some of those PM-species more toxicological evidence is available than for PM<sub>2.5</sub> or PM<sub>10</sub>! So the PM<sub>x</sub> case cannot be excluded either. Moreover strong associations can also be found between cardiopulmonary diseases and for instance traffic noise (Kempen et al., 2002), the quality of housing and the diet of low income families (Eschenroeder and Norris, 2003). It cannot be ruled out that health effects are caused by an accumulation of causes in low income neighbourhoods close to highways of which PM-exposure and NO<sub>2</sub>-exposure are a only a minor part.

Do we know for sure that PM<sub>2.5</sub> is the final answer? Science should not suggest more certainty by selecting only one of the possible explanations, despite that correlations show that such a theory is (a bit) more likely. If scientists cannot falsify a competing theory, policy makers have a problem. They have to deal with the possibility that one of the theories is correct, but they cannot know which one (Jasanoff, 1990; Slovic, 1999). At least not before say 2010 or 2020. They could of course gamble on one theory, but this might be a waste of money (despite the advanced monetarised benefit estimates that go with the theory). How can policy makers minimise the risk of wasting money? How can they minimise health risks? Incertitude is no reason for political lethargy! Especially not as the health effects that occur are real.

### DIFFERENT REALITIES REQUIRE DIFFERENT POLICY STRATEGIES

For the remainder of this analysis I distinguish four ‘stylised’ ways to define the PM-problem or four different perspectives on how reality works. The four theoretical ‘families’ are:

- ‘PM<sub>2.5</sub>’ – focus on transboundary air pollution and secondary inorganic particles
- ‘PM<sub>10</sub>’ – a large part will be PM<sub>2.5</sub> but also the abatement of primary emissions of coarse particles becomes part of the strategy
- ‘PM<sub>x</sub>’ – focus on the traffic related carbonaceous particles and ultrafines
- ‘No PM’ – focus on living conditions in low income neighbourhoods

Each perspective has its own policy strategy (see Table 1).

Table 1: Alternative policy strategies and approaches.

Strategy	Policy Approach
Strategy 1: PM <sub>2.5</sub> is the problem	Focus on secondary particles from SO <sub>2</sub> , NO <sub>x</sub> , NH <sub>3</sub> , VOC and on primary PM <sub>2.5</sub> . Define cost-optimised national emission ceilings for these substances. Take into account the synergy with ozone and NO <sub>2</sub> -exposure and the acidification and eutrophication problem.
Strategy 2: PM <sub>10</sub> is the problem	Focus on cost-effective measures for primary PM sources that contribute most to local exposure, e.g. dust from building industry, cement, wood burning. A transboundary strategy is less important, only EU-harmonisation of technical standards in order to prevent ‘false’ competition at the expense of the health of the local citizens.
Strategy 3: Specific traffic related species are the problem (PM <sub>x</sub> )	Apply stricter international standards for vehicles, ships and refineries (focussed on elemental and organic carbon (EC/OC), heavy metals and primary ultrafines), substitute diesel in captive fleets of urban areas by zero emission vehicles, close densely populated streets for heavy traffic, encourage the use of public transport.
Strategy 4: It is mainly a socio-economic problem (no PM)	Improve living conditions and economic opportunities in poor neighbourhoods (prevent further segregation), circulate heavy traffic around (or under) those neighbourhoods. Design neighbourhoods in such a way that car traffic is minimised. Only reduce those air pollutants that also cause other problems like acidification, eutrophication and ozone formation.

## IN SEARCH OF ROBUSTNESS

If we look at the different strategies, it seems hard to find a way out of the policy dilemma. But there is some light at end of the tunnel:

- a. we can identify measures that are '*no-regret*', i.e. relatively cheap measures that can be part of each strategy (although they are not always the most effective option);
- b. we can identify measures with large *co-benefits* for other environmental or health related problems;
- c. we can identify potential '*regret*' measures, i.e. measures that can worsen the problem if seen from another perspective, e.g. when a trade-off exists between different species of PM, or between other policy fields and the PM-problem.

Measures that are good from all perspectives are for instance measures to reduce car traffic in living areas, either via traffic circulation schemes, the design of communities and the stimulation of public transport. Also measures like cleaner fuels and improvement of the energy efficiency are cost-effective and robust, as well as a ban on tobacco, wood burning and barbecues. Some of these measures are cost-effective but limit the freedom of individual and might thus raise political resistance.

Measures with high co-benefits are for instance the reduction of carbonaceous particles, because they also contribute to the greenhouse effect. Also the reduction of secondary particles (via further reduction of SO<sub>2</sub>, NH<sub>3</sub>, NO<sub>x</sub> and VOC) entails co-benefits because this reduces acidification, eutrophication, ozone formation and NO<sub>2</sub>-exposure.

All particle abatement measures contribute to improvement of the visibility, but it remains unclear how much this co-benefit is worth in the European policy arena.

'Trade-off' measures that are good from one perspective but bad from another perspective are, for instance, technical PM-measures that increase the emissions of ultrafine particles. There are also measures that are part of the greenhouse strategy that would be bad for PM-exposure, such as a shift from petrol to diesel, or the promotion of biomass and waste burning (if not accompanied with strict emission standards).

After scrutinising the different measures that can be part of a robust strategy, still a number of measures will remain that are really gambles. For these measures the policy maker has two options: 1. don't select them and take the risk that harmful health effects will remain to occur or: 2. select them (all) and take the risk of wasting money.

For these measures science can help to quantify the risks in terms of health and money by applying a so-called paradox approach: first select those measures that are part of the optimal solution within a certain perspective (so-called utopian worlds), but then look at the effectiveness of such measures when applied in another perspective (the so-called dystopian worlds). Via the confrontation of perspectives the maximum mistake can be quantified, and this might help the policy maker in finding the right balance between environmental and economic precaution (see Figure 1).

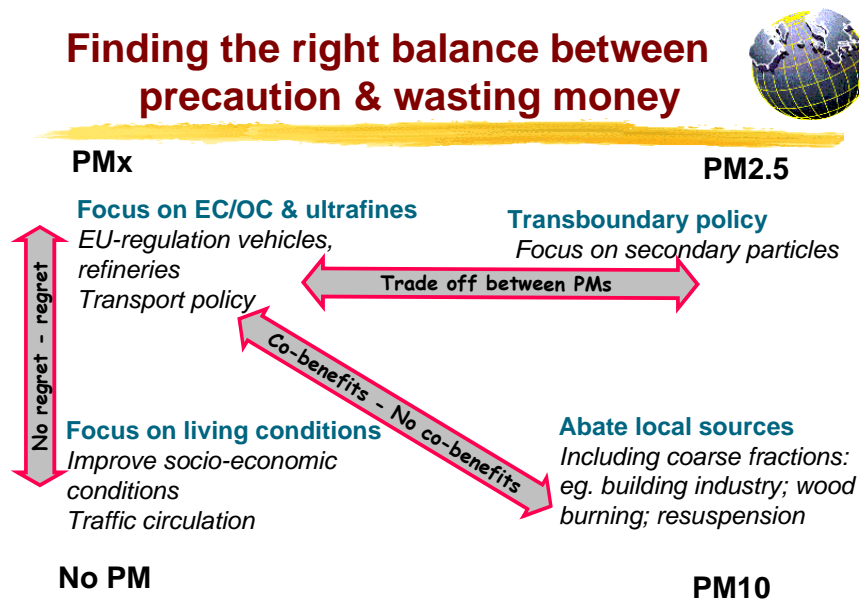


Figure 1: Finding the right balance between precaution and wasting money.

In order to minimize possible mistakes, politicians can combine different strategies and not base their decisions on one theory alone. But in the end they have to decide whether they want to be on the safe side and against what price.

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