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Valuing the Overall Impacts of Air Pollution

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Valuing the overall impact of air pollution

1. Air pollution is associated with a wide range of damaging effects including impacts on human health, personal satisfaction, economic performance and natural ecosystems. Each of these areas is clearly important in considering the total cost of air pollution and consequently need to be reflected in decisions that alter the quality of the air.

2. In order to provide an idea of the order of magnitude of these considerations there is a clear interest in providing a summary statistic to reflect the overall damage attributable to air pollution. Such information could then be used at a very high level for prioritisation across areas, although clearly the potential to address any cost is also required. Given the available evidence it is not possible to produce a value that provides a comprehensive reflection of the range of impacts associated with air pollution.

3. This paper therefore looks to use the existing evidence to produce an indication of the overall health impact of air pollution. The dominant component of the overall health impact is the effect of current levels of fine particles on life expectancy so this is what is examined here. This uses the same methodology as the calculation done for the 2007 Review of the Air Quality Strategy but is based on 2008 rather than 2005 levels of $PM_{2.5}$. Further details of the methodology used can be found in the report of the economic analysis accompanying the strategy[1].

4. When considering an absolute level of health impact it is appropriate to use $PM_{2.5}$ modelling.[2] In addition, it might be considered unrealistic to reduce current levels of particles to zero, when not all particles in the air are anthropogenic. The level of non-anthropogenic $PM_{2.5}$ is assumed to be constant and is estimated to be about 1.418 $\mu g.m^{-3}$ annual average population-weighted mean.[3] This has been subtracted from the modelled $PM_{2.5}$ population-weighted mean in 2008 to give the estimated level of anthropogenic $PM_{2.5}$ (see Table 1 below).

Table 1: $PM_{2.5}$ UK population-weighted mean (Total and Anthropogenic)

Date	$PM_{2.5}$ annual average population-weighted mean (gravimetric, $\mu g.m^{-3}$)	Anthropogenic $PM_{2.5}$ annual average population-weighted mean (gravimetric, $\mu g.m^{-3}$)
2008	10.391	8.973

[1] An economic analysis to inform the Air Quality Strategy. Updated Third Report of the Interdepartmental Group on Costs and Benefits (2007). www.defra.gov.uk/environment/quality/air/airquality/publications/stratreview-analysis/index.htm Section 2.8.2 in Chapter 2.
[2] See section 5.3.3.9 in Chapter 5 of the Updated Third IGCB report for further discussion comparing results using PM_{10} and $PM_{2.5}$ modelling available from www.defra.gov.uk/evidence/economics/igcb

[3] Using the coefficients from the ACS study to calculate the impacts of reductions in the $PM_{2.5}$ levels from the total current level to the non-anthropogenic level of 1.418 $\mu g.m^{-3}$ involves extending the calculation outside the range of the ACS study (the lowest concentration given in the study by Pope *et* al (2002) was 7$\mu g.m^{-3}$). This adds an element of uncertainty to the calculations presented here.

5. The most easily interpretable way to calculate the loss of life expectancy as a result of current exposure to man-made fine particles in 2008 is to compare those born in 2008 and only exposed for the whole of their lifetimes to the natural background of fine particles with those born in 2008 and exposed for the whole of their lifetimes to 2008 levels of fine particles[4]. The concentration in Table 1 was converted into a hazard rate reduction by non-linear scaling[5] of the latest coefficients recommended by the Committee on the Medical Effects of Air Pollutants (COMEAP).[6] The results for 2008 are shown in Table 2. It is estimated that the average loss of life expectancy would be around 6 months in 2008. As with any average, the loss of life expectancy will be greater than this for some people and less than this for others.

Table 2: Estimated loss of life expectancy for a birth cohort[a] (combined male and female) from total current levels of anthropogenic $PM_{2.5}$

	Main result
Date	**0.6%[b]**
2008	176 – 182 days[c] (about 6 months)

[a.] 2008 starting birth cohort assumed to be as in 2005. Birth cohort followed to extinction. Average loss of life expectancy result is independent of birth cohort size. Calculations were done for males and females separately but the results were very close. Combined averaged results for males and females together are shown here.

[b.] Coefficients per $\mu g.m^{-3}$ $PM_{2.5}$ as recommended by COMEAP (Department of Health 2006, COMEAP 2009).

[c.] For a 40 year lag (lower end of range) or no lag (upper end of range). The report by COMEAP (2009) suggested that, although it was not possible to give a precise estimate, a noteworthy proportion of the total effect was likely to appear in the first five years after a pollution reduction i.e. a shorter lag towards the upper end of the range.

[4] This represents the hypothetical removal of anthropogenic $PM_{2.5}$. We consider that people who enquire about the burden of current levels of $PM_{2.5}$ are usually aiming to improve air quality and remove the burden rather than take no action to reduce air pollution. Changing the level of air pollution leads to shifts in the size and age distribution of the population as more people survive from one year to the next so gives a different answer to leaving pollution unchanged.

[5] Linear scaling is a reasonable approximation for small coefficients and small concentration changes. Where changes are larger (as in a total impact calculation), the more precise equation is based on multiplicative scaling of the original study relative risk (RR), taken here as 1.06 for an original concentration change of 10 $\mu g.m^{-3}$. If the new concentration change in population-weighted mean of interest is $-x$ $\mu g.m^{-3}$ (with a negative sign as the analysis usually concerns reductions), then the new RR is calculated as $1.06^{-x/10}$. In this case this gave a new RR of 0.949 or a hazard rate reduction of 5.1%.

[6] The main hazard rate reduction used was 0.6% per $\mu g.m^{-3}$ $PM_{2.5}$ and a range of lag times from 0 to 40 years. Current advice suggests that the lower end of the range of lag times is more likely.

Total life years lost from total current or projected levels of anthropogenic $PM_{2.5}$

6. Of course, the people exposed to current levels of anthropogenic $PM_{2.5}$ are not only those born in 2008 but also people of other ages. These other age groups will not be exposed to the specified anthropogenic $PM_{2.5}$ concentration for the whole of their lives, nor will the loss of life years be counted for the whole of their lives. The older age groups will have had part of their lives before the lifetable follow-up starts and age groups born after the start of lifetable follow-up will continue their lives after follow-up ceases. Therefore, the average loss of life years within each of these other age groups, *within the period of lifetable follow-up*, will be less than that for the birth cohort above. Nonetheless, the smaller loss of life years within each of these other age groups is additive to those in the birth cohort. For this reason, although it is a less familiar concept, a more complete result is given if the answers are expressed in terms of total life years lost across the population.

7. The results in terms of total life years are given in Table 3 below. This table shows that current levels of man made fine particulate air pollution have a marked impact on life years lost. (Note that, although the results are in millions of life years and appear extremely large, the results do represent accumulated life years lost over the entire population, including new birth cohorts, for an extended 100 year period. The total life years lived by the population in this period is about 5 billion).

Table 3: Estimated total life years lost across the UK population from total levels of anthropogenic $PM_{2.5}$

Date	Main result (0.6%)[a]
Total life years lost across the UK	18.2 – 32.4 million life years[b]

[a] Coefficients per $\mu g.m^{-3}$ $PM_{2.5}$ as recommended by COMEAP (Department of Health 2006, COMEAP 2009).

[b] For a 40 year lag (lower end of range) or no lag (upper end of range). The report by COMEAP (2009) suggested that, although it was not possible to give a precise estimate, a noteworthy proportion of the total effect was likely to appear in the first five years after a pollution reduction i.e. a shorter lag towards the upper end of the range.

8. These estimates of total life years have then been used to value the absolute cost of this health impact of fine particle pollution in the UK. Table 3 below presents the monetised values of these impacts based on two sets of assumptions: one based on the AQS methodology and a second updated approach. For the first estimate, in line with the previous estimates, the total number of life years shown in Table 3 has been used to scale the standard lifetable runs; the life years lost in each year (between 2010 and 2109) which have then been valued as described previously in 2005 prices[7]. A second value has also been provided based on the modelled distribution of the impacts over time and based on 2008 prices. The valuation of total impacts is subject to a great deal of uncertainty; for example, since the standard lifetable runs estimate life years lost between 2010 and 2109, the first approach to valuation of the 2005 baseline effects does not incorporate the impact between 2005 and 2009 and is therefore likely to be an underestimate.

9. The range in values presented below reflects different assumptions on the lag time between exposure and the health effects between no lag (high end of the range) and a 40 year lag (the low end of the range). COMEAP declined to provide a quantitative expression of where in the range the answer was likely to lie due to uncertainties in the evidence on the lags involved. Rather, COMEAP provided qualitative text regarding the distribution suggesting that a noteworthy proportion of the total effect was likely to appear in the first five years. For the Monte Carlo analysis undertaken alongside the Air Quality Strategy (2007) this text was converted into a skewed probabilistic distribution with 30 per cent of the impacts within the first five years.[8]

10. To provide an indication of where within this range any impacts are more likely to be this distribution has been applied to the range of monetised benefits. It must however be stressed that the central value is inherently less certain that the estimated range, due to the additional assumptions made.

11. The results of the valuation of total life years are shown in Table 4 below. It is recommended that future work is undertaken to improve the methodology for the valuation of the overall health impact of air pollution.

Table 4: Estimated value of overall health impact from total current or projected levels of anthropogenic $PM_{2.5}$ (£million p.a.)

	Monetised health impact	
Base Year	**Main Result (0.6%)**	**Central Estimate[a]**
Valued in line with the AQS (2005 prices)	£7,710 – £16,904	£14,876
Updated values (2008 prices)	£8,584 – £18,613	£16,379

[a] The most appropriate way of describing these results is to give the full range and to explain that a noteworthy proportion of the effect is likely to occur towards the higher end of the range based on a shorter lag. While it is possible to derive a single estimate by using a distribution of different lags skewed towards shorter lags, this requires further assumptions so cannot be taken to be more certain than the description given in the previous sentence. The underlying evidence is not clear and this uncertainty needs to be reflected in presenting the answer as a range

[7] An economic analysis to inform the Air Quality Strategy. Updated Third Report of the Interdepartmental Group on Costs and Benefits (2007). www.defra.gov.uk/environment/quality/air/airquality/publications/stratreview-analysis/index.htm Section 2.8.2 in Chapter 2
[8] Op cite. Annex 7 Monte Carlo Uncertainty Analysis of AQS measures www.defra.gov.uk/environment/quality/air/airquality/publications/stratreview-analysis/annexes-icgb.pdf.

References

Committee on the Medical Effects of Air Pollutants (COMEAP) (2009). *Long-term Exposure to Air Pollution: Effect on Mortality*. Available at: http://www.dh.gov.uk/ab/COMEAP/DH_108151 (accessed February 2010).

Department for the Environment Food and Rural Affairs (Defra) (2007) An economic analysis to inform the Air Quality Strategy. Updated Third Report of the Interdepartmental Group on Costs and Benefits (2007). Available at: www.defra.gov.uk/environment/quality/air/airquality/publications/stratreview-analysis/index.htm (assessed February 2010)

Department for the Environment Food and Rural Affairs (Defra) (2007) *The Air Quality Strategy for England, Scotland, Wales and Northern Ireland.* Available at: http://www.defra.gov.uk/environment/quality/air/airquality/strategy/index.htm (accessed February 2010).

Department of Health (2006) Committee on the Medical Effects of Air Pollutants. *Interim Statement on the Quantification of the Effects of Air Pollutants on Health in the UK, January 2006*. Available at http://www.dh.gov.uk/dr_consum_dh/groups/dh_digitalassets/@dh/@ab/documents/digitalasset/dh_096803.pdf (accessed February 2010).

Pope, C.A., Burnett, R.T., Thun, M.J., Calle, E.E., Krewski, D., Ito, K., Thurston, G.D. (2002) Lung cancer, cardiopulmonary mortality and long-tem exposure to fine particulate air pollution. Journal of American Medical Association 287(9):1132-1141