Issue 1

Quantification of the non-health effects of air pollution in the UK for PM_{10} objective analysis

A report produced for:
The Department for Environment, Food and Rural Affairs,
The National Assembly for Wales,
The Scottish Executive,
and The Department of the Environment in Northern Ireland

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1 Introduction

1.1 POLICY CONTEXT

The Air Quality Strategy for England, Wales, Scotland and Northern Ireland (AQS, DETR et al 2000) sets the following objectives for PM_{10}, to be achieved by 31 December 2004:

- 50 μgm^{-3} as a 24-hour mean, not to be exceeded more than 35 times a year
- 40 μgm^{-3} as an annual mean, not to be exceeded.

These objectives are consistent with the Stage 1 limit values for PM_{10} included in the first EU Daughter Directive (AQDD), which are to be achieved by 1 January 2005. The 24-hour mean objective is expected to be the more stringent of the two. Indicative Stage 2 limit values for PM_{10} are also included in the first AQDD at 20 μgm^{-3} as an annual mean and 50 μgm^{-3} as a 24-hour mean, not to be exceeded more than 7 times a year, to be achieved by 1 January 2010.

The Government and devolved administrations recognise that the possible health gains from reducing PM_{10} levels are thought to be greater than those for any other pollutant. They are concerned to set sights beyond the immediate need to comply with the AQDD Stage 1 limit values. The Government and devolved administrations have therefore undertaken to assess the prospects of whether the AQS objectives for PM_{10} can be strengthened (DETR et al, 2000).

Analysis of the costs and benefits of different measures to reduce ambient PM_{10} concentrations forms an important part of this PM_{10} objective analysis, being undertaken by the Interdepartmental Group on Costs and Benefits (IGCB).

This report examines the non-health benefits of additional measures that could be put in place to reduce particle levels further than the levels predicted from currently agreed policies. The results of this assessment form an important component of the analysis of the costs and benefits of measures to reduce PM_{10} concentrations.

1.2 OTHER DOCUMENTS

The proposals for a new PM_{10} objective are presented in the Air Quality Strategy consultation document “Proposals for air quality objectives for particles, benzene, carbon monoxide and polycyclic aromatic hydrocarbons” (DEFRA et al, 2001). The technical annex of the consultation document includes PM_{10} emission inventories and projections and a summary of ambient PM_{10} monitoring data in the UK. The models used to estimate future PM_{10} concentrations for both a baseline current policies scenario and an illustrative additional measures scenario are also described in the technical annex. Full details of the modelling methods and results for the baseline scenario are presented in the ‘baseline’ report (Stedman, et al 2001a). Projections for alternative scenarios incorporating the impact of additional policy measures to reduce PM_{10} are required to assess the costs and benefits of these measures in comparison with the baseline. Projections for these additional measures scenarios along with details of the packages of measures that they represent, are presented in a companion report (Stedman et al, 2001b) and summarised in the technical annex (DEFRA et al, 2001). Analyses of the health benefits (Stedman *et al*, 2001) and non-health benefits (this report) of the additional measures contribute to “An Economic Analysis of the Air Quality Strategy Objectives for Particles” (DEFRA, 2001) along with an examination of the costs of possible measures to reduce PM_{10} emissions and concentrations (AEA Technology, 2001).

2 Overview Of Non-Health Effects Associated With The Particle Reduction Measures

The objectives relating to PM_{10} in the AQS are defined by concerns over human health and are not explicitly aimed at reducing the impacts to materials, crops, ecosystems etc. Nevertheless, additional non-health benefits will occur as a result of reductions in ambient concentrations of PM_{10}, SO_2, NO_x and ozone.

2.1 DIRECT EFFECTS

The key direct impacts from reductions in PM_{10} concentrations relate to building soiling, and visibility, as summarised in Table 1. Only the effects associated with building soiling have been given a full monetary valuation.

Table 1: Direct Effects of Additional Measures to Reduce Particle Levels

Effect	Quantification
Building Soiling	✓
Reduced Visual Range	✗

2.1.1 Building Soiling

Soiling of buildings by particles is one of the most obvious signs of pollution in urban areas. The soiling of buildings includes both “utilitarian” and historic buildings and causes economic damages through cleaning and amenity costs. Particles may also be involved in damage to building fabric. Building soiling is likely to be one of the key non-health benefits of possible additional measures to reduce PM_{10} concentrations in 2010.

Soiling is an optical effect (a darkening of reflectance) and results primarily from the deposition of airborne particulate matter to external building surfaces. The interim IGCB Report (DETR, 1999) considered in detail the factors that can affect the degree of soiling. These factors include (QUARG, 1996): the blackness per unit mass of smoke; the particle size distribution; the chemical nature of the particles; substrate-particle interfacial binding; surface orientation; and micro-meteorological conditions. Similarly, different types of particulate emission have different soiling characteristics. They can be differentiated by fuel type with the use of dark smoke emission factors (Newby *et al*, 1991; Mansfield *et al*, 1991). For example, diesel emissions have a much higher soiling factor relative to petrol or domestic coal emissions. This is due to their higher particulate elemental carbon (PEC) content (QUARG, 1993). PECs have a high optical absorption coefficient and their hydrocarbon content means they are very sticky and much less water soluble than suspended soil particles (which are readily removed by rain washing (Mansfield, 1992)). Therefore, a PEC particle landing on a surface is more likely to strongly adhere than other particulate matter.

2.1.2 Visibility

Visibility, perhaps more clearly expressed as ‘visual range’, is a function of the rate of light extinction over distance through scattering and absorption. A number of pollutants have potential effects on visibility including primary particles, NO_2 and sulphate and nitrate aerosols.

Visibility is not perceived to be a major issue in Europe, perhaps reflecting the fact that although there have been periods when air pollution has a clear and dramatic effect on visibility, such events are rare. Quantification of both the change in visual range and valuation of the loss of amenity through reduction in visibility is possible, though totally reliant on data from the USA. Holland *et al* (1999) used these data in analysis on behalf of the UNECE Task Force on Economic Aspects of Abatement Strategies and calculated substantial damages, exceeded only by effects on health. However, given the lack of concern over this issue in Europe, and restraints on the analysis (in particular relating to short term fluctuations in pollution levels), Holland (et al) concluded that the results were not reliable. Therefore, quantification of the benefits to visibility from particulate reductions in the UK is not currently possible with confidence and hence associated damages are not assessed here.

2.2 INDIRECT EFFECTS

Further benefits will arise from the additional measures in terms of the impacts these measures have on other pollutants. The main pollutants affected are SO_2 and possibly ozone and NO_x. A number of the proposed transport measures will also have impacts on reductions in noise levels. Table 2 summarises these indirect impacts arising from measures to reduce PM_{10} concentrations.

Table 2: Indirect Effects of Additional Measures

Pollutant	**Effect**	**Quantification**
SO_2*	Material damage	✓
Ozone	Damage to materials	✖
SO_2	Effects on crop yield	✓
Ozone	Effects on crop yield	✖
Noise	Amenity/disturbance	✖
SO_2	Ecosystem damage	✖
NO_x	Ecosystem damage	✖
*quantification is limited to damages from 'utilitarian buildings'		

Insufficient data exists to provide a robust quantification, and monetary evaluation, of each of the effects identified in table 2. For ecosystem damage a qualitative approach based upon critical loads exceedance has been adopted, to provide an indicative measure of the likely level of impact overall. A qualitative assessment has also been carried out for noise effects.

3 Methods for Quantifying Non-Health Effects

The methodology adopted within this study follows closely that presented in the interim IGCB Report [1998]. New developments in the field have led to changes in the methodological approach for some of the effects analysed; these developments are outlined in the following sections. For those impacts in which the methodology is unchanged, readers are invited to refer to the original interim IGCB report [1998] for a fuller explanation of the quantification.

The calculation of non-health effects has been undertaken using pollution data and receptor data at 1km^2 grid resolution across the whole UK, and with the use of dose-response functions linking pollution concentrations with relevant effects.

3.1 QUANTIFICATION OF DIRECT EFFECTS

3.1.1 Valuing Building Soiling

Although soiling damage has an obvious cause and effect, the quantification of soiling damage is not straightforward. Soiling can impact on a number of different materials, including natural stone, paint, concrete, rendering and also glass (windows - though these are excluded from the current analysis through a lack of data). Measurement data of reflectance (and industry experience) show that soiling appears to be very rapid on clean surfaces, following initial exposure (i.e. it is non-linear). Moreover, evidence shows that reflectance measurements oscillate, indicating cleansing and re-soiling. This may result from the fact that soil derived particles once deposited on materials are more likely to be removed by rainfall than deposited diesel particles.

The main approach quantifies soiling damages using cleaning costs (in the absence of WTP data). However, this approach does not usually include amenity costs and it is therefore clear that cleaning cost estimates will be lower than total damage costs resulting from the soiling of buildings (though they do represent an indication of minimum damage costs). To take account of this, an alternative approach has been used within the analysis here, with a function which links population weighted particle concentrations to cleaning and amenity costs (summarised below). Within such an assessment, PM_{10} may not be the most relevant functional unit. Instead black smoke or TSP (total suspended particulates) are better metrics for assessing damages. For this reason, we have adjusted the functions and economic values to give greater weight to primary particles.

Dose-Response Functions for Soiling Damages from Particulates

Building soiling damages can be calculated using the approach by Rabl et al (1998) used for quantification in the interim IGCB Report. The Rabl et al study looks at total soiling costs (i.e. the sum of repair cost and amenity loss). It showed that for a typical situation where the damage is repaired by cleaning, the amenity loss was equal to the cleaning cost (for zero discount rate); thus the total damage costs are twice the cleaning costs. The study recommended the following function:

$S_i = a * P_i * \Delta TSP_i$ (where $a = b * 2$)

S_i = Annual soiling damage at receptor location i.
P_i = Number of people in location i.
ΔTSP_i = Change in annual average TSP (Total Suspended Particles) $\mu g/m^3$.
a = WTP per person per year to avoid soiling damage of $1 \mu g/m^3$ particles.
b = Cleaning costs per person per year from a concentration of $1 \mu g/m^3$ of TSP.

This function allows a site specific assessment, linking reductions in particle concentrations with population. This function will be used for UK wide quantification. A value of 0.5 ECU (33 pence) for cleaning costs has been used, based on Parisian data.

Knowledge of the characteristics of different types of particulates suggests that only primary particles have soiling effects. We assume that the secondary particles formed from SO_2 (e.g. sulphate aerosol and ammonium sulphate) and from nitrates (e.g. ammonium nitrate and non-specific nitrate aerosol) are very different in nature and will not lead to the same loss of reflectance. Therefore, to calculate the baseline values and the benefits of the suggested measures, only primary PM_{10} emissions have been used. However, the use of this approach requires the economic values above to be adjusted to take account of the proportion of primary to secondary particulates in the original air pollution mixture. This adjustment has been made, based on the original Rabl study. This implies an increase from PM_{10} to $PM_{10\ (primary)}$ of a factor of three.

3.2 INDIRECT IMPACTS

3.2.1 Valuing Materials damage

The effects of atmospheric pollutants on buildings have been well documented over many years and clear mechanisms linking pollution to material damage have been identified. These permit separation of pollutant impacts from the deterioration of materials caused by the natural acidity of rainwater, heating and freeze-thaw cycles and so on. Sulphur dioxide has emerged as the key pollutant associated with material erosion, both directly (through dry deposition) and indirectly through the formation of secondary pollutants (acidic deposition). Particulates are thought to play a role as a catalyst to erosion, particularly in the conversion of dry deposited SO_2 into sulphuric acid (Hamilton, 1994; Cooke and Gibbs, 1994). These damages have been recorded on modern buildings and other modern infrastructure as well as historic buildings.

Stock at Risk

The stock at risk data was derived from Butlin et al. (1994). Data on building numbers and the area of various construction materials that form the envelope of buildings in the UK are taken from survey information, brought together through the European Commission's ExternE programme (EC, 1998). It was assumed that half the building stock was unsheltered.

Dose-Response Functions

The analysis here uses the data set of the UNECE Integrated Collaborative Programme (ICP) (Tidblad et al, 1998). This programme has looked at atmospheric corrosion of materials across Europe using a uniform experimental protocol and is preferable to other pieces of work because of the length of exposure time (8 years) and the large number of sites. Dose-response functions were presented for limestone, sandstone and zinc. Additional functions for paint were used. In all cases, functions were implemented for unsheltered materials only.

Calculation of Repair Frequency

This approach assumes that maintenance or repair is carried out after a given thickness of material has been lost. The calculations are based on averages although the loss of material will obviously not be uniform across a building.

Estimation of Economic Damage

The correct valuation of damage would be in terms of the willingness to pay (WTP) to avoid damage but as no assessments of this type are available repair/replacement costs of building components are used as a proxy estimate of economic damage.

The costs of repair and maintenance figures used in the analysis have been based on data from ECOTEC (1986; 1992) updated to current prices. Estimated repair costs are taken from unit cost factors for each of the materials for which assessment was performed. This analysis is complicated by uncertainty about the time at which people would take action to repair or maintain their property and has therefore assumed that individuals act rationally and take action when the critical thickness loss has occurred.

Other Benefits from Reductions in Materials Damages

There may be additional benefits which must be added to reductions in “utilitarian” building damage. The most important of these possibly relates to amenity losses for historical buildings and objects of cultural value. Willingness to pay to protect historical buildings from damage is likely to be higher than that for ‘utilitarian’ buildings; costs of restoration could also be higher in many cases. However, while there are lists of historic buildings, there is not an accessible inventory that describes material types, presence of fine carvings, etc. Without this it is not possible to come up with an estimate of variation in repair frequency for any given building at different pollution levels. There are also issues with aggregation of individual estimates and benefit transfer from one building to another. Although research is developing in this area, there are currently no available estimates of historic building damage that can be used for a quantitative analysis.

Additional benefits would occur from reductions in NO_x and related acidic deposition, though these will be small compared to the SO_2 effects above. Potentially larger effects may arise from changes in ozone concentrations. Ozone is known to damage some polymeric materials such as plastics and rubbers and these effects were described and quantified in the previous analysis. Predicting the changes in ozone concentrations from reductions in NO_x and VOC is complex and may lead to both positive and negative effects, as described in the previous IGCB report. The effects of the measures in changing ozone concentrations have not been assessed in this study and so it is not possible to quantify any possible impacts or benefits.

3.2.2 Valuing crop damages by SO_2

Although ozone is regarded as the main pollutant of concern with respect to crops, sulphur dioxide can also influence crop yield and quality. The effects of SO_2 can be both positive and negative, and can occur through both direct and indirect mechanisms. The analysis below quantifies the direct effects using a dose-response approach. At UK ambient concentration levels these effects are likely to be beneficial as a consequence of the depletion of sulphur nutrient levels in soil. The approach is the same as that presented in the interim IGCB Report [1998], though UK crop production and crop prices[1] have been updated to current values.

Dose-Response Functions for Crop damage from SO_2

Baker *et al* (1986) produced the following function from work on winter barley:

% Yield Loss = 9.35 - 0.69(SO_2) where SO_2 = annual mean ppb concentration

One problem with work in this area, is that experimental exposures rarely extend below an SO_2 concentration of about 15 ppb which is assumed to correspond to a 0% yield reduction. However, a large number of experiments have shown that low levels of SO_2 are capable of stimulating growth; so it cannot be assumed that there is no effect on yield below 15 ppb, nor that any effect will be detrimental. As few rural locations in Europe experience SO_2 levels greater than 15ppb, the equation above is not directly applicable. To resolve this an exposure-response function of the form suggested by Fowler *et al* (1988) was produced with the following outcome:

$y = 0.74(SO_2) - 0.055(SO_2)^2$ (from 0 to 13.6 ppb) where y = % yield loss
$y = -0.69(SO_2) + 9.35$ (above 13.6 ppb)

Another study by Weigel *et al* (1990) presented data for barley which was used to calculate the following relationship:

$y = 10.92 - 0.31(SO_2)$ where SO_2 measured in $\mu g/m^3$

It is considered that this function may be applied directly without the need to consider how best to extrapolate back to 0 as the background mean concentrations which provided the control levels in this study were low (about 3ppb).

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[1] Valuation of crop losses uses prices from United Nations Food and Agricultural Organisation (FAO). These represent world prices, which are taken to be a closer approximation to real resource costs than prices in the UK, where of course there is major intervention through the Common Agricultural Policy.

4 Results of the analysis

The results presented are associated with reduction of a 0.75 $\mu g/m^3$ population weighted annual mean PM_{10} (or $PM_{2.5}$) gravimetric concentration, from an illustrative package of additional measures, as defined in the report "An Economic Analysis of the Air Quality Strategy Objectives for Particles" (DEFRA, 2001) and associated documents. The PM_{10} reduction is taken relative to the baseline (changes averaged over the base years 1996 to 1999), occuring in 2010 and maintained thereafter.

4.1 DIRECT EFFECTS

4.1.1 Reduction in Building Soiling from Additional Measures

The estimated soiling costs (for PM_{10}) using the dose-response approach for the 1998 and 2010 baseline were estimated at £ 337 million/year and £ 177 million/year respectively. This implies an estimated reduction in damages from building soiling over the period 1998 to 2010 of £160 million/year on a Business as Usual scenario.

The benefits in terms of reduced building soiling damages from the additional measures are presented in the table below. The estimated figures show an annual benefit in 2010 of £12 million from the additional transport measures (particulate traps, introduction of 10ppm sulphur diesel and retrofitting) and £41 million for the stationary measures, implying a total annual benefit in 2010 of £52 million. The results are summarised in Table 5.3. The total benefit comprises cleaning costs and amenity costs.

Table 3: Estimated Benefits to Materials from Reductions in PM_{10}

Date	**Total Damage (£Million)**	**Total Annual Benefit (£M) relative to 2010 Baseline**
1998	336.6	
2010	176.7	159.8 *
Scenario		
Transport	-	11.8
Industry	-	40.5
Total	**-**	**52.3**

* Change in benefit between 1998 to 2010

4.2 INDIRECT EFFECTS OF ADDITIONAL MEASURES

4.2.1 Material Corrosion by SO_2 and Acid Deposition

Table 4 quantifies the estimated benefits to materials from reductions in SO_2. The annual benefit in 2010 from the illustrative package of additional measures is small at less than £1m.

Table 4: Estimated Benefits to Materials from Reductions in SO_2

Date/Scenario	Total Annual Benefit (£m) relative to 2010 Baseline
1998	-
2010	25.9 *
Scenarios	0.86
Total	**0.86**

* Change in benefit between 1998 to 2010

4.2.2 Crop Damage by SO_2

Table 5: Estimated Benefits to Crops from Reductions in SO_2

Date/Scenario	Total Annual Benefit (£m) relative to 2010 Baseline
1998	
2010	-21.4
Scenarios	-0.9
Total	**-0.9**

The Table shows there are dis-benefits, in terms of reduced crop yields, from the 1998 and 2010 baselines, because crop fertilisation is reduced. The further reductions in SO_2 emissions from introducing the stationary and transport measures reduces these fertilisation effects further, so that the scenarios lead to a dis-benefit of £0.9 million. However, the results do not quantify the likely benefits from SO_2 reductions on liming and indirect effects and so it is expected that overall dis-benefits would be smaller. There are also likely to be additional benefits on crop yields from changes in ozone concentrations. These effects were discussed and quantified in the previous IGCB report. The effects of measures in reducing ozone concentrations have not been assessed in this study and so it is not possible to quantify these benefits, though we stress they may be significant.

4.2.3 Impacts on Ecosystems

There has been no direct assessment made of the effects of the abatement measures identified here on ecosystems. The main pathway for these effects is through changes in emissions of NOx and SO_2.

The 2001 consultation draft of the NEGTAP Report on Acidification, Eutrophication and Ground Level Ozone in the UK provides a current indication of the extent of the problem of the exceedence of critical loads for acidification and eutrophication in the UK in 2010. Exceedence of critical loads is not spread evenly across the country, but is particularly concentrated in high altitude areas in England and Wales. Many such areas are designated (e.g. Areas of Outstanding Natural Beauty) and as such will tend to attract many visitors and be associated with high amenity values.

The tables below present estimates of the change in critical load exceedences for acidification and eutrophication in 2010, compared with 1995 to 1997, following the implementation of the Gothenburg Protocol. For acidification of ecosystems, the area of critical load exceedences is estimated to fall from 71% to 47% compared to 1995-97. For eutrophication by nitrogen, exceedence of critical loads of ecosystems are estimated to fall from 39% to 30% compared to 1995-97.

Table 6: Percentage of ecosystem areas exceeding critical loads for acidity in 1995-97 and 2010

Ecosystem Type	1995 to 1997	2010
Acid grassland	80	52
Calcareous grassland	37	20
Heathland	69	47
Coniferous woodland	68	41
Deciduous woodland	80	69
Freshwaters	15	8
All Ecosystems	**71**	**47**

Source: NEGTAP

Table 7: Percentage exceedences of critical loads of ecosystems for eutrophication by nitrogen in the UK in 1995-97 and 2010

Ecosystem Type	1995 to 1997	2010
Acid grassland	26	16
Calcareous grassland	0	0
Heathland	54	38
Coniferous woodland	84	77
Deciduous woodland	96	95
All Ecosystems	**39**	**30**

Source: NEGTAP

Note that the magnitude of reduction of the area of ecosystems exceeding the critical load for acidification following the full implementation of the Gothenburg Protocol may be as high as 23%. However lags in recovery indicate the actual date at which recovery reaches 23% may be much later than 2010.

4.2.4 Benefits from Reductions in Noise Levels

The package of additional measures to reduce particle concentration levels described in previous chapters included potential transport measures. An indirect benefit of some of these measures might be to reduce noise levels.

The introduction of cleaner vehicles has some noise benefits, as vehicles fuelled by LPG and CNG as well as electric/fuel cell powered vehicles are less noisy than diesel. Note, however, these measures will only reduce engine noise; they have no benefits in reducing rolling noise (i.e. noise from contact between road surface and wheels), though in urban areas where low speeds dominate, engine noise dominates over rolling noise.

The possible benefits of various transport scenarios in terms of reduced noise emissions from different types of vehicles have been described in qualitative terms in Table 8 below. Note that the first three measures only have been included in the illustrative package of measures for ambient concentration modelling.

Unfortunately, without a detailed analysis of the scenarios, it is not possible to accurately assess what level of benefits might arise from these scenarios in terms of reduction to ambient noise exposure. To do so would require accurate modelling of the specific areas, the baseline traffic flows and speeds, the levels of noise reductions from alternative fuel vehicles, etc. Also, if a precise quantification of the noise impacts is not available in the first place, it is not possible to obtain reliable monetary estimates of the latter by applying standard values for changes in dB(A) exposure, themselves a source of considerable uncertainty.

Nonetheless, an initial analysis has been made of possible benefits, which indicates that relative to the total non-health benefits of pollution reductions, these benefits will be low.

Noise reductions resulting from stationary sources have not been assessed.

Table 8: Noise Benefits Resulting From Transport Scenarios

Scenario	**Effect on Noise**
Scenario 1 – mandatory particulate traps for new light duty and heavy duty diesel vehicles	None assumed.
Scenario 2 – early introduction of sulphur free diesel	None.
Scenario 3 – short term retrofitting programmes. Retrofits to 600 taxis (LPG), 500 trucks (CNG) and 100 buses (CNG).	There will be benefits for retrofitting taxis and trucks with LPG and CNG, e.g. for light-duty vehicles the use of CNG leads to around a 50% lower perceived noise level compared to diesel.
Scenario 4 – promotion of CNG for new heavy duty vehicles. 500 CNG vehicles in urban areas by 2005.	Large benefits in terms of reduction of engine noise, e.g., a HGV running on gas can be up to 6 dB(A) quieter than a similar diesel vehicle.
Scenario 5 – zero emission buses in urban areas. In year 2010, assumes 1750 new buses. Cumulative zero emissions buses in place by 2010 = 5250 buses.	Large benefits in terms of reduced engine noise. At low speeds, Battery Electric Vehicles, Hybrid Electric Vehicles and Fuel Cell powered Vehicles can achieve up to 90% noise pollution reduction. However there might be an increased safety risk to pedestrians and cyclists due to a reduced awareness of the vehicle's presence.

5 CONCLUSIONS

This report has examined the non-health benefits of additional measures that could be put in place to reduce particle levels further. The main non-health benefits, which are directly linked to reductions in particles are reduced building soiling and improvements to visibility. In the case of building soiling, monetary estimates are presented which comprise cleaning costs and an allowance for amenity loss. The (partial) value of these benefits has been estimated at £52 million per annum. Quantification of the benefits to visibility has not been attempted in this report due to a lack of reliable evidence.

Measures to reduce particles will also impact on other pollutants thus creating indirect benefits. Indirect non-health benefits which have been quantified in this report relate to material corrosion and crop damage from change in SO_2 concentrations. The net change in benefits from SO_2 effects on materials and crops are negligible. There are other potential effects to materials and crops from changes in ozone levels, and from noise benefits for transport measures, though these have not been quantified. The preliminary results indicate that the non-health benefits are relatively small in relation to the costs of the additional measures.

Table 5.9: Non-Health Benefits Resulting From Measures to Reduce Particles

Impact Category	**Estimated Total Benefit (£ million per annum)**
Building Soiling	£52 million
Material Corrosion (SO_2)	£0.9 million
Damage to Crops (SO_2)	-£0.9 million
Total	**£52 million**

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