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Working Group on Effects

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REVIEW OF AIR POLLUTION EFFECTS

# INDICATORS AND TARGETS FOR AIR POLLUTION EFFECTS

Report by the Extended Bureau of the Working Group on Effects

## I. INTRODUCTION

1. At its meeting in February 2009, the Extended Bureau of the Working Group on Effects (the Bureau, the Chairs of the Task Forces and the Joint Expert Group on Dynamic Modelling, the representatives of the programme centres of the International Cooperative Programmes (ICPs) and invited experts) decided to report in detail selected workplan items common to all programmes. These included: (a) key monitored and modelled parameters of annex 2 to the Guidelines on reporting of monitoring and modelling of air pollution effects (ECE/EB.AIR/2008/11, hereinafter, the Guidelines); (b) the merits of different options for target-setting in 2020 and non-binding aspirational targets for the year 2050; and (c) policy-relevant effects indicators and their links to integrated modelling. The results are presented in accordance

with the Convention's 2009 workplan (ECE/EB.AIR/96/Add.2, item 3.1 (d) (ii, iv and v)) approved by the Executive Body at its twenty-sixth session in December 2008.

2. The text and the tables in this document include the following general notations: x = monitored (or the number of sites, countries, and the period), X = modelled or calculated, – = neither monitored nor modelled, n.a. = not applicable to the programme, * = not defined in the Guidelines annex 2, [] = concentration, and I or II = level I or II sites of the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests).

3. In addition, following acronyms are used, in alphabetical order: Al = aluminium, ANC = acid neutralizing capacity, AOT = accumulated ozone concentrations above the selected threshold in parts per billion (ppb), BC/Al = ratio of base cations to aluminium in soil solution, BS = soil base saturation, Cd = cadmium, C/N = soil carbon-to-nitrogen ratio, CL = critical load, DM = dynamic modelling, EU = European Union, Hg = mercury, HM = heavy metals, $HNO_3$ = nitric acid, JEG = Joint Expert Group, K = potassium, MCPFE = Ministerial Conference for the Protection of Forests in Europe, Mg = magnesium, N = nitrogen, $NO_2$ = nitrogen dioxide, NO3 = nitrate, $N_{total}$ = total N concentration in soil, $O_3$ = ozone, P = phosphorous, Pb = lead, $PM_{2.5}$ and $PM_{10}$ = fine and coarse particulate matter, POP = persistent organic pollutant, ppb = part per billion, S = sulphur, $SO_2$ = S dioxide, $SO_4$ = sulphate, SOMO35 = annual sum of maximum daily mean eight-hour $O_3$ concentrations above 35 ppb, TF = throughfall, TOC = total organic carbon, and WHO = World Health Organization.

## II. KEY PARAMETERS FOR REPORTING ON MONITORED AND MODELLED AIR POLLUTION EFFECTS

4. This section summarizes the key parameters selected reporting on monitored and modelled effects. The review focuses on effects; therefore, data on climatic variables, air concentrations and deposition are not included. The grouping of the availability and details of data follows that in the Guidelines' annex 2, with additional indications on programme-specific sources. Tables 1–8 present the status reported by the programmes as of 1 June 2009.

### A. Acidification of aquatic ecosystems

5. Data from the International Cooperative Programmes on Assessment and Monitoring of Acidification of Rivers and Lakes (ICP Waters) and on Integrated Monitoring of Air Pollution Effects on Ecosystems (ICP Integrated Monitoring) indicated that ANC, and to a lesser extend pH, correlated with decreasing $SO_4$ concentrations in waters. Chemical recovery was occurring at some sites. TOC concentrations in surface waters increased at sites in Europe and North America, possibly a consequence of chemical recovery. Biological recovery lagged behind, but had been observed in Canada, the Czech Republic, the Nordic countries and the United Kingdom of Great Britain and Northern Ireland. Modelling of critical and target loads, in collaboration with the International Cooperative Programme on Modelling and Mapping of Critical Loads and

Levels and Air Pollution Effects, Risks and Trends (ICP Modelling and Mapping), confirmed that S deposition reductions led to decreasing exceedance. Critical loads would continue to be exceeded with current legislation.

**Table 1. Acidification of aquatic ecosystems**

| Parameter | ICP Waters | ICP Integrated Monitoring | ICP Modelling and Mapping |
|---|---|---|---|
| ANC | 179 (1990–2001) | x | X |
| pH | 179 (1990–2001) | x | X |
| Alkalinity | 179 (1990–2001) | – | X |
| [Al] | n.a. | – | X |
| TOC | 5,005 (1990–2004) | x | n.a. |
| Calculated CL, exceedance, threshold criteria | 72 (Europe only), limit value of ANC | X, –, – | X, X, X |
| Invertebrates * | 60 (6 countries, selected periods during 1980–2001) | – | n.a. |
| DM * | Methodological development in cooperation with EU projects | x | X |

## B. Acidification of terrestrial ecosystems

6. Observations of ICP Forests and ICP Integrated Monitoring suggested no clear indications on soil recovery. $SO_4$ accumulated in the past is being released to aquatic ecosystems. $NO_3$ concentrations and pH showed no general trends. BS did not continue decreasing, but no general increase was yet observed.

7. ICP Modelling and Mapping calculated that critical and target loads were still exceeded in some parts of Europe. Emission reductions and their timing were linked to decreasing exceedance.

**Table 2. Acidification of terrestrial ecosystems**

| Parameter | ICP Forests | ICP Integrated Monitoring | ICP Modelling and Mapping |
|---|---|---|---|
| BS | xx | x | X |
| ANC leaching | x | x | X |
| pH | xx | x | X |
| [$SO_4$] | x | x | n.a. |
| [$NO_3$] | x | x | X |
| Total [Al] | x | – | n.a. |
| BC/Al | x | x | X |
| Calculated CL, exceedance, threshold criteria | X, –, – | X | X, X, X |
| DM * | – | x | X |

*Note*: For ICP Forests, x = level II only, xx = levels I and II.

## C. Eutrophication of terrestrial ecosystems

8. Atmospheric N input to terrestrial ecosystems can lead to unbalanced nutrient status of foliage. N deposition affected the nutrient status on ICP Forests plots of pine and spruce. The foliage status, related to all nutrients, was unbalanced or insufficient at 30 per cent of the sites. Assessment of epiphytic lichen flora at 25 remote ICP Integrated Monitoring sites showed that N determined the occurrence of acidophytic lichens. Atmospheric N was retained in ecosystems, indicated by low leaching levels. Leaching depended on C/N ratio, and also on temperature, when C/N was low. ICP Modelling and Mapping calculated that critical loads remained widely exceeded in Europe with no recent decrease. Highest exceedance was found in areas with intensive livestock husbandry.

**Table 3. Eutrophication of terrestrial ecosystems**

| Parameter | ICP Forests | ICP Integrated Monitoring | ICP Vegetation | ICP Modelling and Mapping |
|---|---|---|---|---|
| $N_{total}$ | x | x | n.a. | X |
| $NO_3$ leaching | x | x | n.a. | X |
| C/N | xx | x | n.a. | X |
| Ratio of nutrients in foliage (N/P, N/K, N/Mg) for dominant and key species | xx | – | – | n.a. |
| Calculated CL, exceedance, threshold criteria | X | X | n.a. | X, –, – |
| Empirical CL, exceedance, threshold criteria | – | x | n.a. | x, –, – |
| N concentration in mosses * | n.a. | – | x | n.a. |
| Effects on biodiversity * | x | x | – | X |
| DM * | x | – | n.a. | X |

*Note*: For ICP Forests, x = level II only, and xx = levels I and II.

### D. Ground-level ozone effects on vegetation, materials and health

9. No trends were detected on $O_3$ concentration in air, nor on its effects on vegetation and health in the last 10–15 years. Seven per cent of species on 67 ICP Forests plots from seven countries in Europe showed $O_3$ symptoms during a survey for the period 2002–2004. The concentration-based critical level for forests was frequently exceeded by on 86–98 per cent of 57 ICP Forests plots in France, Italy, Spain and Switzerland for the period 2000–2002.

10. Results from the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops (ICP Vegetation) indicated that the concentration-based method for crops underestimated the effects across Europe, in particular in Northern Europe, as effects were detected in areas below the concentration-based critical level. Flux-based method for crops predicted the observed widespread occurrence of $O_3$ damage better than concentration-based maps for the period 1995–2004.

11. According to the results from the Joint Task Force on the Health Aspects of Long-range Transboundary Air Pollution (Task Force on Health) about 14–61 per cent of the urban population in Europe was exposed to ambient $O_3$ concentrations. They exceeded the EU health protection target for the period 1997–2006.

**Table 4. Ground-level ozone effects on vegetation, materials and health**

| Parameter | ICP Forests | ICP Vegetation | ICP Materials[a] | Task Force on Health |
|---|---|---|---|---|
| Growth and yield reduction | – | x | n.a. | n.a. |
| Leaf and foliar damage | x | x | n.a. | n.a. |
| Climatic factors | – | x | n.a. | n.a. |
| Exceedance of AOT values | x | x/X | n.a. | n.a. |
| Accumulated flux exceedance | x | x/X | n.a. | n.a. |
| Degree of soiling | n.a. | n.a. | x | n.a. |
| Acceptable and/or tolerable levels of soiling | n.a. | n.a. | x | n.a. |
| SOMO35 | n.a. | n.a. | n.a. | X |
| Maximum daily eight-hour average concentration * | n.a. | n.a. | n.a. | X |

[a] International Cooperative Programme on Effects of Air Pollution on Materials, including Historic and Cultural Monuments.

### E. Particulate matter effects on materials and health

12. $PM_{10}$ was positively correlated with soiling of materials and buildings. Soiling comprises, inter alia, the disagreeable appearance of old buildings, the increased cleaning of greenhouses and less energy from solar cells. The changing visual appearance of buildings might be unacceptable even if the base material was virtually unaffected. Related cleaning costs could be substantial. To achieve a 20-year cleaning interval, $PM_{10}$ levels should be $<10\ \mu g\ m^{-3}$, based on public perception through questionnaires of a tolerable soiling level for cultural heritage.

13. $PM_{2.5}$ was associated with the loss of 4,900,000 years of life and 492,000 annual premature deaths in Europe. Highest population-weighted concentration levels of $PM_{2.5}$ (>23 µg $m^{-3}$) and $PM_{10}$ (50µg $m^{-3}$) were found in Central and South-Eastern Europe. No changes in PM effects on health were foreseen with current legislation.

**Table 5. Particulate matter effects on materials and health**

| Parameter | ICP Materials | Task Force on Health |
|---|---|---|
| Degree of soiling [of modern glass] | x | n.a. |
| Acceptable and/or tolerable levels of soiling | x | n.a. |
| Annual average $PM_{2.5}$ | – | X |
| Epidemiological studies | n.a. | X |
| $PM_{10}$ * | – | X |

## F. Heavy metal effects on ecosystems and health

14. Hg levels were up to three times higher than pre-industrial levels in lake sediments at Scandinavian sites of ICP Waters, due to long-range atmospheric transport. Hg in freshwater fish was frequently above the limit recommended for human consumption in Scandinavia and North America. ICP Vegetation surveys showed that the majority of metal concentrations in mosses decreased since 1990, except for chromium and Hg. On 4,000 ICP Forests level I plots, critical limits were exceeded by 5–25 per cent, depending on the metal, based on data from late 1980s to early 1990s. Mass balance studies at ICP Integrated Monitoring sites indicated considerable retention of Cd, copper, nickel, Pb and zinc, amounting to 80–95 per cent of total input. ICP Modelling and Mapping calculated that critical loads for heavy metals were exceeded more and wider for Hg and Pb than for Cd.

**Table 6. Heavy metals effects on ecosystems and health**

| Parameter | ICP Forests | ICP Waters | ICP Integrated Monitoring | ICP Vegetation | ICP Modelling and Mapping | Task Force on Health |
|---|---|---|---|---|---|---|
| [HM] in: | | | | | | |
| (a) Water and lake sediments | n.a. | x | – | n.a. | n.a. | n.a. |
| (b) Forest soils | x | n.a. | x | n.a. | X | n.a. |
| (c) Mosses | n.a. | n.a. | – | x | n.a. | n.a. |
| Calculated CL, exceedance, critical thresholds for: | | | | | | |
| (a) Forest soils | x, x, – | – | x | – | X, X, x | n.a. |
| (b) Crops | n.a. | n.a. | n.a. | – | X, X, x | n.a. |
| (c) Health | n.a. | n.a. | n.a. | n.a. | n.a. | x |
| [HM] in biota * | – | x | – | x | n.a. | n.a. |

### G. Persistent organic pollutants effects on ecosystems and health

15. ICP Waters had no observational data on POPs. Based on its literature study, POPs were found in fish from remote locations, such as Arctic and alpine areas, and in human milk. Time series suggested that concentrations were decreasing for POPs that were no more in use.

**Table 7. Persistent organic pollutants effects on ecosystems and health**

| Parameter | ICP Waters | Task Force on Health |
|---|---|---|
| Concentrations levels in: | | |
| (a) Vital organs of aquatic biota | – | n.a. |
| (b) Lake sediments | – | n.a. |
| Biomarkers of human exposure | n.a. | x |

### H. Multiple pollutant effects on materials

16. A substantial part of materials corrosion is due to atmospheric pollution. Corrosion rates due to past and present exposure to multiple pollutants were monitored and calculated. Savings in prevented corrosion after the implementation of the 1994 Protocol on Further Reduction of Sulphur Emissions was estimated at 9 billion United States dollars annually in Europe. A recent estimate of annual losses due to corrosion by atmospheric pollutants in the United States of America was 276 billion United States dollars. Monitoring showed that lower $SO_2$ levels have decreased corrosion due to multiple pollutants in urban areas, but they have remained significantly higher than in rural areas.

**Table 8. Effects of multiple pollutants on materials**

| Parameter | ICP Materials |
|---|---|
| Mass loss of materials, including cultural heritage (carbon steel, zinc) | x |
| Acceptable and/or tolerable levels of corrosion | x |
| Corrosion of limestone * | x |

## III. MERITS OF OPTIONS FOR NON-BINDING ASPIRATIONAL TARGETS FOR THE YEAR 2050 AND TARGET-SETTING IN 2020

17. The effects-oriented activities have considered aspirational targets to describe potential status of the environment and human health. Aspirational targets were set up for the year 2050. These help with setting targets for 2020, which should be in the pathway for aspirational targets. Both 2050 and 2020 targets were proposed to be used for integrated assessment modelling. Tables 9–14 below describe targets for 2050 and 2020 for aquatic and terrestrial ecosystems, materials and health, as proposed by the programmes.

**Table 9. Targets for aquatic ecosystems for 2050**

| | **Targets for 2050** | **Indicators** | **Remarks** |
|---|---|---|---|
| ICP Waters | Healthy fish population in all acid sensitive lakes and rivers in Europe and North America | Presence of fish population with a normal age structure; no exceedance of CL | |
| ICP Integrated Monitoring | Waters providing natural quality prerequisites | ANC in surface waters >20 µeq $l^{-1}$; no exceedance of CL | |
| ICP Modelling and Mapping | Protect ecosystem structure and function, including biodiversity, and ecosystems services for human well being | No exceedance of CL and critical levels | Attainment as soon as possible |
| | | No violation of chemical and biological critical limits | All ecosystems fully recovered |
| JEG on DM | Protecting appropriate ecological receptors | Good status; favourable conservation status. (Note: historical and future land management affect target loads for biodiversity) | Historical reference states potentially unachievable |

**Table 10. Targets for aquatic ecosystems for 2020**

| | **Targets for 2020** | **Indicators** | **Remarks** |
|---|---|---|---|
| ICP Waters | Healthy fish population in most acid sensitive lakes and rivers in Europe and North America | Presence of fish in all acid sensitive rivers and lakes; reduction by 50 per cent of the area where CL was exceeded in 2010 | - |
| ICP Integrated Monitoring | Waters providing natural quality prerequisites | Reduced CL exceedance | - |
| ICP Modelling and Mapping | Improved status or reduced decline of ecosystem structure and function | Reduced CL exceedance, including no exceedance | Gap closure of exceedance to aim proportional reductions in all exceeded areas; attainment as soon as possible; some ecosystems fully recovered |

**Table 11. Targets for terrestrial ecosystems for 2050**

| | **Target for 2050** | **Indicators** | **Remarks** |
|---|---|---|---|
| ICP Forests | Full recovery from previous atmospheric inputs | CL for acidification and eutrophication not exceeded; balanced nutrient concentrations in tree foliage | Atmospheric pollutants affect forest ecosystem functioning |
| | Healthy and vital trees | Reduced tree crown defoliation reduced; decrease of abiotic and biotic damage induced mortality; natural regeneration of all site-specific tree species; abiotic and biotic damages at sustainable levels (no conflict with economic and ecological targets) | Changing environmental condition and increasing frequency of extreme events endanger forest ecosystem stability |
| | No further loss of biodiversity; increased biodiversity in natural forests | Ground vegetation, tree species and epiphytic lichen composition; stand structure, including deadwood volume and composition | Atmospheric inputs and changing climate induce shifts in species composition |
| | Forest management adapted to maximum C store | Amount of C store above and below ground | Healthy forests mitigate climate change effects through C store and sequestration in biomass and soils |
| ICP Integrated Monitoring | Recovery from previous atmospheric inputs; healthy forest ecosystems; no further loss of biodiversity | Acidification: soil Al/Bc ratio <1; no CL exceedance. Eutrophication: no further decrease of soil C/N ratio; no ground vegetation changes; no increase in nitrophilic species; no increase in N leaching; no CL exceedance. Heavy metals: no critical limit exceedance of Pb, Cd and Hg in humus layer; no CL exceedance | - |
| ICP Vegetation | Avoid all detectable $O_3$ damage to receptors and reduction in ecosystem services, such as C sequestration | Crops and trees: large reduction in $O_3$ flux. (Semi-)natural vegetation: reduction in $O_3$ flux. (Note: all calculated with generic flux model.) | Secure food production and quality; maintain healthy forests and secure timber production; prevent loss of plant biodiversity and maintain ecosystem services; flux-based models include climatic changes |
| ICP Modelling and Mapping | Protect ecosystem structure and function, including biodiversity, and services for human well-being | No exceedance of CL and critical levels | Attainment as soon as possible |
| | | No violation of chemical and biological critical limits | All ecosystems fully recovered |
| JEG on DM | See remarks in table 9 for aquatic ecosystems. | | |

**Table 12. Targets for terrestrial ecosystems for 2020, to be compared with table 11**

| | Targets for 2020 | Indicators | Remarks |
|---|---|---|---|
| ICP Forests | Healthy and sustainably managed forest ecosystems: ongoing recovery from previous atmospheric inputs | ibid. | ibid. |
| | Improved tree health and vitality in an integrated manner | No significant increase in tree crown defoliation; no increase in mortality; increased natural regeneration of main tree species; Reduced abiotic and biotic damage | ibid. |
| | No further loss of biodiversity; Concept of naturalness [a] | ibid. | ibid. |
| | No reduction in forest C pools | ibid. | ibid. |
| ICP Vegetation | Avoid most detectable $O_3$ damage to receptors and ecosystem services | Crops and trees: reduction in the modelled generic $O_3$ flux; (Semi-) natural vegetation: reduced exceedance of AOT40 critical level of 3 and 6 months | ibid. |
| ICP Integrated Monitoring | Improved ecosystem conditions | Reduced CL exceedance | - |
| ICP Modelling and Mapping | Improved status or reduced decline of ecosystem structure and function | Reduced CL exceedance | Gap closure of exceedance to aim proportional reductions in all exceeded areas |

[a] One of 27 indicators for sustainable forest management by MCPFE; it is being developed to specify status and targets of natural forest types in Europe, which are naturally low in species diversity.

**Table 13. Targets for protecting materials of infrastructure and cultural heritage monuments for 2050 and 2020 by ICP Materials**

| Year | Target | Indicators | Remarks |
|---|---|---|---|
| 2050 | Corrosion | Carbon steel <16 $\mu m\ a^{-1}$; zinc < 0.9 $\mu m\ a^{-1}$; limestone < 6.5 $\mu m\ a^{-1}$ | Indicator values correspond to 2.0 times current background levels |
| | Soiling | Loss in reflectance (<35 per cent compared to unsoiled surface after 20 years) | Tolerable value is based on replies from people confronted with photographs of different soiling levels of actual monuments |
| 2020 | Corrosion | Carbon steel <20 $\mu m\ a^{-1}$; zinc <1.1 $\mu m\ a^{-1}$; limestone <8.0 $\mu m\ a^{-1}$ | Indicator values correspond to 2.5 times current background levels |
| | Soiling | Loss in reflectance (<35 per cent compared to unsoiled surface after 10 years) | ibid. 2050 |

*Note*: All indicators are calculated with dose-response functions.

**Table 14. Targets for human health for 2050 and 2020 by the Task Force on Health**

| Year | Target | Indicators | Remarks |
|---|---|---|---|
| 2050 | *WHO Air Quality Guidelines* | Daily maximum eight-hour mean of $O_3$; annual average concentration of $PM_{10}$, $PM_{2.5}$, $NO_2$, $SO_2$, Pb, Cd and Hg | Guidelines levels might be reduced in future evaluation, based on evidence collected with more sensitive methods |
| 2020 | ibid. | ibid. | Present trends of $PM_{10}$ and $NO_2$ indicated that targets were not likely to be reached by 2020 in many regions and countries in Europe |

## IV. QUANTIFIED POLICY-RELEVANT INDICATORS LINKED TO INTEGRATED ASSESSMENT MODELLING

18. A number of policy-relevant indicators, some included in the Guidelines' annex 2, were currently monitored or calculated by the effects-oriented programmes. This section presents the links between indicators and integrated assessment modelling.

19. The Working Group on Effects and the Task Force on Integrated Assessment Modelling collaboratively evaluate effects of different emission scenarios with the GAINS (Greenhouse Gas and Air Pollution Interactions and Synergies) model. In addition, all ICPs analyse scenarios in the ex-post assessment using indicators not included in the GAINS model. Future Task Force reports, which earlier included scenario-specific critical load and AOT exceedance, will be completed with ex-post assessment results. These include dynamic modelling, empirical critical loads, dose-response relationships, evaluations at selected surface water sites and flux-based method of ozone for selected terrestrial ecosystems.

20. ICP Forests monitors indicators listed both in the Guidelines' annex 2 and those specified by MCPFE. These include deposition (mainly S, N, and base cations) and parameters to calculate critical loads for acidification and eutrophication. The programme also covers chemical soil properties, such as pH, BS, cation exchange capacity, C/N and soil organic C. Tree crown defoliation integrates forest health status, which reacts to many biotic, abiotic and anthropogenic stresses. Composition of ground vegetation species composition indicates effects on biological diversity.

21. ICP Waters monitors biotic indicators, which can be transferred to biodiversity indicators. They include presence and absence of key fish species, and fraction of observed invertebrates relative to expected number of species. Well-established dose-response relationships link S and N deposition with water chemistry – which ANC represents – as well as ANC with biota (fish and invertebrates). Dynamic modelling of historic and future ANC predicts time to chemical recovery of surface waters.

22. ICP Vegetation has developed methods for $O_3$ that are technically ready for use in integrated assessment. These include the generic flux model for crops and trees, and

concentration-based critical levels for (semi-)natural vegetation. A generic $O_3$ flux for the latter is being developed.

23. ICP Materials has established indicators for corrosion and soiling of materials. They are defined with: (a) reliable corrosion and soiling results from a one-year material sample exposure; (b) available dose-response functions; and (c) available acceptable and/or tolerable levels. Indicator materials for corrosion are carbon steel, zinc and limestone. No indicator materials for soiling fulfil all criteria as of yet. $PM_{10}$ is currently used as an indicator for soiling, combined with dose-response functions from literature and a generic tolerable level.

24. ICP Integrated Monitoring has calculated site-specific critical loads for acidification, eutrophication and heavy metals as well as their exceedance with modelled and measured deposition. Sites are located in protected areas such as Natura 2000. Critical load exceedance is being linked with effect indicators, e.g. concentrations, budgets and biodiversity.

25. ICP Mapping and Modelling has compiled and mapped critical loads and their exceedance and has modelled non-attainment of selected critical limits. These chemical risk indicators are traditionally used in integrated assessment. The programme derived empirical critical loads of eutrophication and dose-response relationships on biological effects from field experiments. The use of calculated and empirical critical loads in the ensemble assessment of impacts helps to improve the robustness of the results.

26. The Task Force on Health has established the loss of life expectancy and years of life lost as most robust impact indicators of long-term $PM_{2.5}$ exposure. The Task Force's modelling comprises estimates of population exposure, based on annual average $PM_{2.5}$ concentration in selected population, and concentration-response functions from epidemiological studies. The Task Force employs demographic information such as age-specific population structures, life tables and mortality specific to age and causes of death. Impacts of $O_3$ concentrations are calculated with population-specific SOMO35 data or model estimates, concentration-response functions from time-series studies and total population numbers. Results are expressed as numbers of annual attributable deaths. Monetary value, in terms of years of life lost or statistical deaths, can be applied for economic evaluation of all health impact parameters.

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