United Nations ECE/EB.AIR/WG.1/2011/3

Economic and Social Council

Distr.: General
18 July 2011

Original: English

Economic Commission for Europe

Executive Body for the Convention on Long-range Transboundary Air Pollution

Working Group on Effects

Thirtieth session
Geneva, 27–29 September 2011
Item 4 of the provisional agenda
Recent results and updating of scientific and technical knowledge

Impacts of air pollution on ecosystems, human health and materials under different Gothenburg Protocol[1] scenarios

Executive summary — Interim report by the Working Group on Effects

I. Analysed scenarios

1. The objectives of this analysis, decided by the Bureau of the Working Group on Effects, are to:

(a) Provide information on the effects of air pollution on ecosystems, human health and materials to support decisions for the revision of the Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (Gothenburg Protocol);

(b) Demonstrate the application of new science and indicators, developed since 1999, to illustrate the potential impact of policy/decisions on the environment, human health and materials;

(c) Illustrate the effectiveness of emission scenarios to improve the environment and human health.

2. This analysis was carried out by the International Cooperative Programmes (ICPs) and the Joint Task Force on the Health Aspects of Air Pollution (Task Force on Health) under the Working Group between October 2010 and February 2011. The analysis is based on scenarios of air pollutant emissions (sulphur (S), nitrogen (N), ozone (O_3) and

[1] 1991 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone.

particulate matter (PM)) provided by the Task Force on Integrated Assessment Modelling and the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP) in October 2010 (described in report 1/2010 by the Centre on Integrated Assessment Modelling (CIAM))[2]. Relevant data was formatted by the Coordination Centre for Effects (CCE) in order to facilitate the ICPs modelling work and comparison with field data. Results were presented and discussed at different meetings under the Convention on Long-range Transboundary Air Pollution (Air Convention) between February and May 2011.

3. The scenarios referred to in this report are:

(a) NAT2000: historical data for the year 2000 based mainly upon national information;

(b) NAT2020: data generated under a current legislation scenario for 2020 based mainly upon national information about future economic projections;

(c) PRI2020 and PRI2030: data generated under a current legislation scenario for 2020 and 2030 and based mainly upon economic projections developed by the PRIMES model;[3]

(d) MTFR2020: data based upon a scenario assuming all technically feasible technologies being implemented by 2020.

4. NAT and PRI projections are considered to represent "baseline" scenarios: they provide estimates of emissions if no new regulations are implemented. MTFR represents the reduction that would be obtained if the most stringent regulations were implemented. Any decision leading to some emission reduction will lead to a situation between the baseline and the MTFR scenario. Further details on these projections and scenarios are specified in CIAM report 1/2010.

5. Emissions scenarios have undergone some revisions since October 2010, mainly to respond to requests from the Working Group on Strategy and Review. It is therefore expected that an update of this work will be carried out in summer/autumn 2011 to ensure a close correlation to the emission scenarios that will be used in the latest stage of the revision of the Gothenburg Protocol, expected at the end of 2011 or early 2012.

II. Impacts and trends

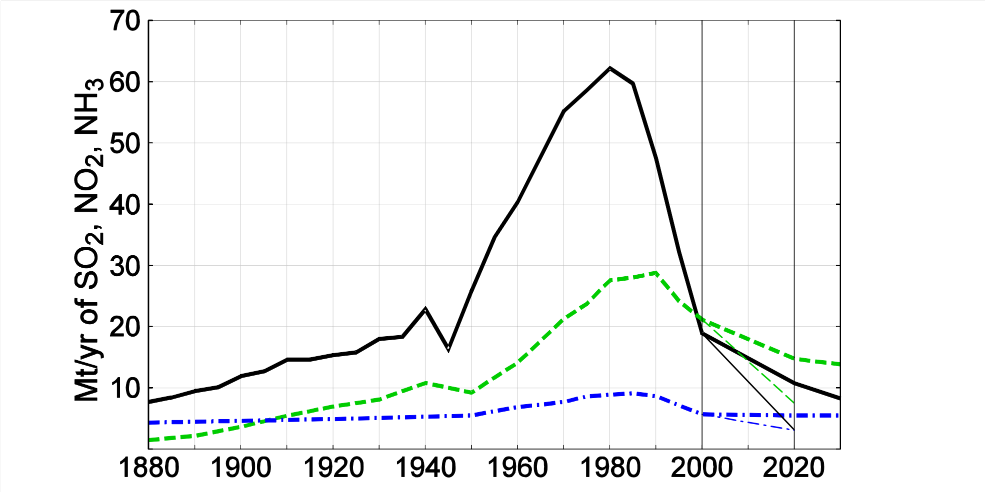
6. Air pollution regulations, including protocols to the Air Convention, have led to significant decreases in sulphur and nitrogen concentrations in the air and in their deposition to ecosystems. The trends show a more than 70 per cent decrease in sulphur emissions in Europe in 2010 as compared with 1980, while total nitrogen emissions have decreased by about 50 per cent in the same period (see figure 1). The consequences of these decreased emissions have been observed through the monitoring network designed under the Air Convention and this report illustrates some of the results.

[2] The report is available from the International Institute for Applied Systems Analysis website at http://gains.iiasa.ac.at/reports/CIAM/CIAM_report_1-2010_v2.pdf.

[3] PRIMES energy system model developed by the European Commission.

Figure1

1880–2030 development of European emissions of S (solid line), oxidized N (dashed line) and reduced N (dashed-dotted line)



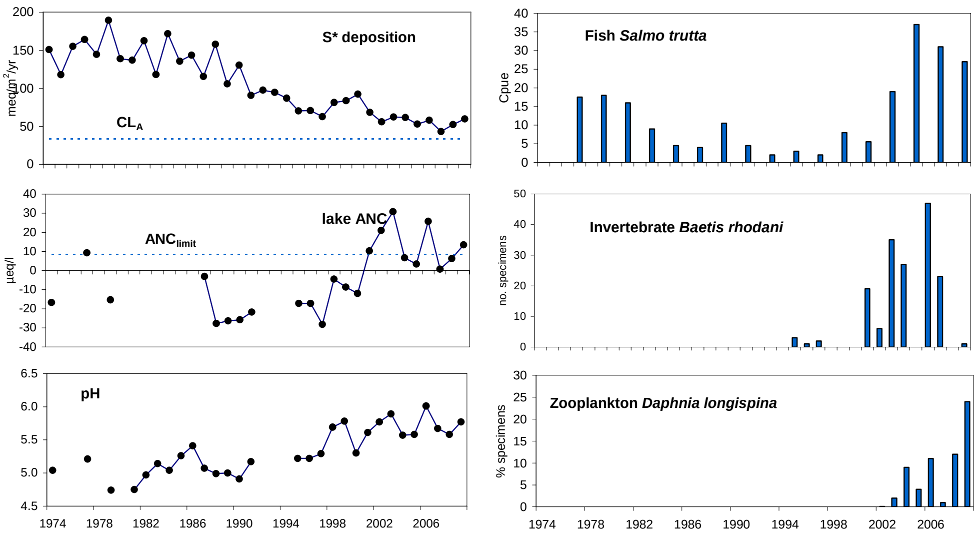
Notes: From the year 2000 emissions are calculated with the NAT2000 scenario. Beyond 2020, the NAT2020 and PRI2030 scenarios are used. The thin lines point to the MTFR scenario for 2020. (Please note: PRI2020 is very close to NAT2020.)

7. The Working Group on Effects has, over several decades, developed, compiled and collated a large amount of multidisciplinary scientific knowledge related to the impact of air pollution on ecosystems, human health and materials. The monitoring and modelling carried out by the ICPs and Task Forces enable analysis of the dynamics and trends of the biotic and abiotic parameters of ecosystems. Three examples have been selected to illustrate the impacts of the increase and decrease of air pollution on the environment. More results are available on the websites of the Working Group on Effects, the ICPs and the Task Forces, as well as in the scientific literature.

8. *Example 1***.** Monitoring in Lake Saudlandsvatn in southern Norway over 35 years shows the (modelled) decrease in pollutant deposition since the 1970s (see figure 2), leading to an increase in the concentrations of certain critical chemical parameters, such as the acid neutralizing capacity (ANC) and pH, to conditions that allow biological recovery to begin. Thus, after a dramatic collapse of the trout population in the 1980s, trout numbers increased again in the 2000s, together with invertebrates and zooplankton, not seen for many years.

Figure 2

Long-term deposition, lake chemistry and lake biology monitoring data for Lake Saudlandsvatn, an ICP Waters[4] site in southern Norway

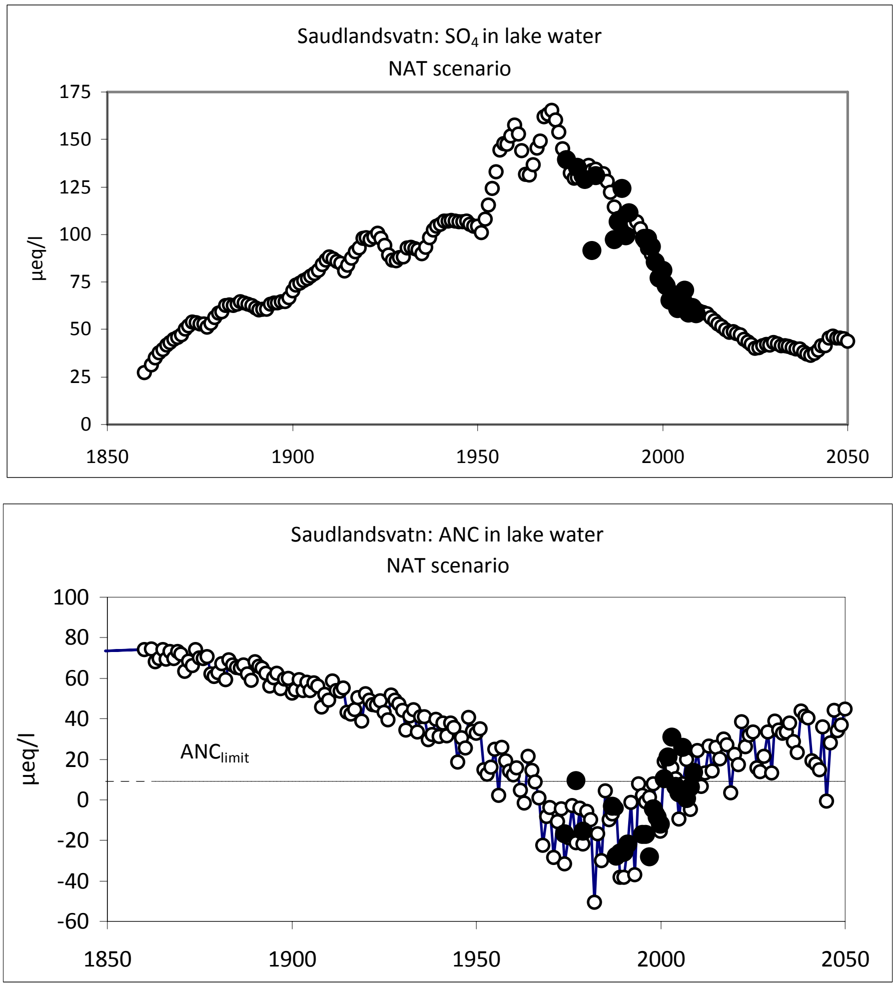


Notes: Shown are non-marine S (S*) deposition, lake ANC and pH, catch-per-unit effort (CPUE) of fish (brown trout), number of specimens collected of the acid-sensitive mayfly *B. rhodani*, and per cent of specimens collected of the acid-sensitive zooplankton species *D. Longispina*.

9. Emission scenarios for 2020 and beyond predict a decrease of acidifying compounds and, according to these scenarios, the dynamic modelling (figure 3) confirms the recovery of the ANC, although it lays close to the critical limit and may not reach its pre-1900 levels by 2050. This example illustrates the recovery of an acidified ecosystem, the delay time between emission reduction and biological recovery, and the limits of this recovery.

[4] International Cooperative Programme on Assessment and Monitoring of the Effects of Air Pollution on Rivers and Lakes.

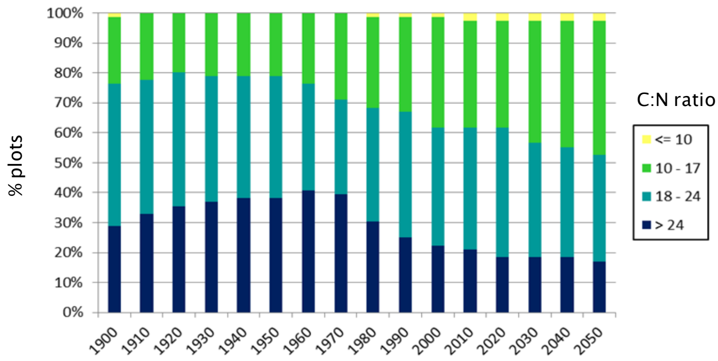
Figure 3
Concentrations of sulphate (SO_4) and ANC in Lake Saudlandsvatn measured (red squares) and simulated (blue diamonds) with the MAGIC model



Notes: The future simulated values assume S* deposition as specified by the NAT scenario data sets for 2000 and 2020, and at constant level past the year 2020.

10. *Example 2*. The International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) has modelled the evolution of soil parameters on 77 plots across Europe. In relation to acidification, soil pH appears to respond as expected to sulphur deposition increase and decrease, while base cation supply in soils shows a lasting decrease. While the emissions trends reduce the acidifying impact, the number of sites with increasing nitrogen concentrations in the soils has been rising since the 1950s and this rise is modelled to continue after 2020 (figure 4). Observations at ICP Waters sites suggest that soils have been accumulating nitrogen for the last 30 years or more. Extra nitrogen in soils may lead to a shift toward eutrophic ecosystems (as illustrated by figure 4) and a loss of species with preference for nitrogen-poor environments. In addition, it is expected that at some stage soils will become saturated and nitrogen will leach into waters. This may increase nutrient imbalance in fresh and coastal waters.

Figure 4
Overall trends for carbon to nitrogen (C:N) ratio modelled by VSD+ model[5] and classified by nutrient levels



Notes: Future scenario is based on NAT2020. The proportion of eutrophic (C:N between 10–17) and hypertrophic (C:N smaller than 10) sites is expected to increase beyond 2020.

11. *Example 3*. The International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops (ICP Vegetation) has reported visible injury symptoms attributed to ozone pollution in 16 European countries since 1990, with the total number of records of symptoms exceeding 600. A new impact indicator for ozone (the phytotoxic ozone dose (PODy)) has been developed, which gives a better correlation between the locations where ozone damage was reported and maps of ozone flux (PODy) than maps of AOT40.[6]

12. Using the NAT scenarios, economic losses due to ozone for wheat were estimated to be €3.2 billion in the 27 States of the European Union (EU-27) plus Switzerland and Norway in 2000, decreasing to €1.95 billion in 2020. Although percentage wheat yield reduction is predicted to decline in NAT2020, only a very small reduction in the proportion of grid squares exceeding the critical level is predicted. Proportional reductions in yield and economic value for tomato, an important crop for southern areas, were similar to those for wheat for NAT2020 compared with NAT2000.

[5] (Very simple) soil acidification model developed by Coordination Centre on Effects.
[6] Ozone cumulative exposure index.

Predicted impacts of ozone pollution on wheat and tomato yield and economic value, together with critical level exceedance in EU-27 plus Switzerland and Norway in 2000 and 2020 under the current legislation scenario (NAT scenario)

	Wheat		*Tomato*	
	NAT2000	NAT2020	NAT2000	NAT2020
Economic losses (billions of euros)	3.20	1.95	1.07	0.63
Proportion of EMEP grid squares exceeding critical level*	84.8	82.2	76.4	49.5
Mean percentage yield loss*	13.7	9.1	9.4	5.7

Note: Analysis was conducted on a 50 x 50 kilometre EMEP grid using crop values in 2000 and an ozone stomatal flux-based risk.

* Calculated for the grid squares where the crop is grown.

III. Discussion and conclusion

13. The monitoring and the modelling carried out under the Working Group on Effects shows that the magnitude of the impact of air pollution will decrease under baseline (NAT2020 and PRI2020) and MTFR scenarios. However, as illustrated above and summarized below, none of the impacts considered (acidification, eutrophication, effects of ozone, material soiling and corrosion, human health effects) are expected to disappear by 2020 under either scenario.

A. Acidification

14. International Cooperative Programme on Modelling and Mapping of Critical Loads and Levels and Air Pollution Effects, Risks and Trends (ICP Modelling and Mapping) results suggest that acidification will be of concern in 2 to 4 per cent of the EMEP area. This is consistent with ICP Waters and the International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems (ICP Integrated Monitoring), whose observations and modelling show that the most acidified sites will not recover by 2020. Moreover, ICP Forests calculations suggest that most ICP Forests sites will be protected from acidification under the baseline scenario, and all will be protected under the MTFR scenario. However, a tendency towards low base cation saturation in forests soils is expected. In the long term, this may have deleterious consequences on the nutritional status of soils, as well as on the base cations supply to freshwaters.

B. Eutrophication

15. Eutrophication remains, and will remain, a widespread problem. In terrestrial ecosystems, excesses of nitrogen inputs leads to accumulation of nitrogen in soils and eventually leaching into waters. This can promote changes in species diversity and susceptibility of vegetation to insects, fungal diseases or drought. Calculations from ICP Modelling and Mapping were supported by assessments from ICP Integrated Monitoring and ICP Forests: in 2020, under the baseline scenario, more than 60 per cent of EU-27 and 35 per cent of EMEP areas will still be at risk of eutrophication. The amplitude of the exceedances will range between 2 and 5 kilograms per hectare per year (kg/ha/yr) at ICP Integrated Monitoring sites which are situated in background areas distant from local sources. Maximum exceedance values (approximately 10 kg/ha/yr) were calculated for the

Netherlands by ICP Modelling and Mapping. Also, as shown in figure 4, under baseline projections, the proportion of eutrophic (C:N between 10–17) and hypertrophic (C:N smaller than 10) sites is expected to continue to increase at ICP Forests monitoring plots beyond 2020.

16. The contribution of ammonia to ecosystem damage is expected to remain important across Europe under the baseline scenario. In 2020, concentrations over most of Europe will remain greater than the critical level for lichen and bryophytes (1 microgram per cubic meter ($\mu g/m^3$)) according to the baseline scenario. In large areas, especially in cattle-raising areas (Brittany in France, the Netherlands, northern Italy), average annual concentrations will remain greater than the critical limit for higher plants (2 $\mu g/m^3$–4 $\mu g/m^3$).

C. Ozone

17. Ozone affects human health, natural vegetation, forests, grasslands and crops. ICP Vegetation has shown that ozone pollution may partly suppress the global carbon sink via its adverse effects on plant growth. It can also make vegetation less able to withstand periods of drought. Areas at particular risk of ozone impact are Southern Europe, but also include most of the central and southern parts of Northern Europe. Projected air pollution reductions may lead to lower ozone concentrations but, under the baseline scenario, for example, wheat yield losses may still be greater than 5 per cent in more than 80 per cent of the EMEP grid squares. The Task Force on Health showed that currently in the EU-25 there are 21,000 premature deaths every year due to high ozone concentrations (>35 parts per billion or 70 $\mu g/m^3$). Only a small decrease in this premature death number is expected with the full implementation of the current legislation.

D. Particulate matter

18. PM causes respiratory and cardiovascular mortality and morbidity and over 300,000 premature deaths are attributed to them every year in Europe. In the United States of America, a recent study demonstrated that health improvement was associated with the decrease in PM levels over 20 years. In this study, a 7.3-month increase in life expectancy was attributed to a decrease of fine PM ($PM_{2.5}$) by 10 $\mu g/m^3$. The Task Force on Health has compared the health risk associated with black carbon to that associated with $PM_{2.5}$. They concluded that, although there is sufficient evidence of health risk associated with black carbon, it is insufficient to justify replacing $PM_{2.5}$ by black carbon as a health-relevant indicator of particulate air pollution.

19. PM and other air pollutants also cause soiling and corrosion, which damage building materials and cultural heritage sites. The International Cooperative Programme on Effects of Air Pollution on Materials, including Historic and Cultural Monuments (ICP Materials) have established dose-response relationships and proposed targets for 2020 and 2050. These targets correspond to tolerable levels of corrosion or soiling. For instance, the proposed tolerable level for soiling results in coarse PM (PM_{10}) levels less than 20 $\mu g/m^3$ for 2020 and less than 10 $\mu g/m^3$ for 2050. Calculations done at the scale of the EMEP grid (50 x 50 km^2) suggest that, with the baseline scenario, the more stringent 2050 targets would be achieved on nearly 88 per cent of the EMEP area, while on almost all of the remaining 12 per cent the 2020 targets would be achieved. Comparisons with field data, however, show that these calculations are too optimistic and that urban areas are pollution hot spots which are likely to remain at higher risk than shown at the 50 x 50 km^2 grid scale used in this assessment.

E. Economic impacts and impacts on ecosystem services

20. Currently economic impact assessments are performed in the greenhouse gas and air pollution interactions and synergies (GAINS) model only for human health indicators. However, several of the ICPs are developing their work towards associating the impacts described above to ecosystem services or economic costs, or both. As described above, recent data from ICP Vegetation suggests economic losses of €3 billion due to ozone damage to one European crop (wheat). ICP Materials indicators may also be associated with specific costs in the future. Impacts of air pollution on ecosystems may be evaluated, in terms of availability of drinking water, resilience of forests to pest attack and to drought (which may have a cost in term of wood quality) and with regard to quality of recreational areas (with, for instance, the impact on recreational fisheries).

21. In summary, even after full (hypothetical) implementation of the MTFR scenario for 2020, many areas would remain at risk from the adverse impacts of air pollution on ecosystems (including crops), human health and materials. Acidification will be of least concern in the future. However, considerable adverse impacts of eutrophication (nitrogen pollution), ozone and PM (including black carbon) will remain over large areas of Europe.