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EXECUTIVE BODY FOR THE CONVENTION ON
LONG-RANGE TRANSBOUNDARY AIR POLLUTION

Working Group on Effects
(Twenty-third session, Geneva, 1-3 September 2004)
Item 6 of the provisional agenda

THE 2004 SUBSTANTIVE REPORT ON THE REVIEW AND ASSESSMENT OF AIR POLLUTION EFFECTS AND THEIR RECORDED TRENDS: EXECUTIVE SUMMARY

Report by the Bureau of the Working Group on Effects
with the assistance of a consultant and in collaboration with the secretariat

Introduction

1. At its eighteenth session, the Executive Body decided to initiate the preparation of the 2004 substantive report on the review and assessment of present air pollution effects and their recorded trends (ECE/EB.AIR/71, annex IV, item 3.1.2). The Working Group on Effects at its twentieth session, approved in principle the draft outline of the report (EB.AIR/WG.1/2001/3, annex VIII, as amended). At its twenty-first session, the Working Group approved the annotated outline of the substantive report (EB.AIR/WG.1/2002/5, as amended) and requested its Bureau to continue to organize the work (EB.AIR/WG.1/2002/2, para. 54). Pursuant to the 2003 work-plan for the implementation of the Convention adopted by the Executive Body at its twentieth session, the draft 2004 substantive report should be presented to the Working Group on Effects, at its twenty-second session (ECE/EB.AIR/77/Add.2, item 3.1.2). At its twenty-second session, the Working Group on Effects (EB.AIR/WG.1/2003/2, para. 51) approved the draft of the 2004 substantive report, summarized in document EB.AIR/WG.1/2003/3/Add.1, taking note of

suggestions for amendment, and decided to submit it to the Executive Body for information. It also agreed that the Bureau in collaboration with the secretariat should take the necessary steps to ensure that the report was finalized and published for the Working Group's twenty-third session and the Convention's twenty-fifth anniversary.

2. The Bureau of the Working Group on Effects coordinated the finalization of the substantive report and its executive summary, presented below, in close collaboration with the International Cooperative Programmes (ICPs) and the Task Force on the Health Aspects of Air Pollution and with the assistance of a consultant, Mr. G. Fenech (Canada), and the secretariat.

I. BACKGROUND

3. The history leading to the Convention on Long-range Transboundary Air Pollution can be traced back to the 1960s, when scientists demonstrated the interrelationship between sulphur emissions in continental Europe and the acidification of Scandinavian lakes. The Convention was the first multilateral treaty aimed to protect the environment against the growing threat of acid precipitation and photochemical smog. It was adopted in 1979 and entered into force in 1983. Eight protocols followed, specifying further commitments by Governments to control air pollution.

4. The need to have sound scientific underpinning of future decisions on controlling air pollution was fully recognized at the adoption of the Convention. As a result:

(a) The Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP) was recognized within the text of the Convention itself; and

(b) In April 1983, the Working Group on Effects was established to address the effects of sulphur compounds and other major air pollutants on human health and the environment.

5. In the early years of the Convention, discussions on the damage of air pollution on forests and freshwaters, as well as the harmful effects on materials and on human health, provided the driving force for action and the development of the early protocols. International Cooperative Programmes (ICPs) were established under the Working Group on Effects to carry out more detailed studies and to begin long-term monitoring of affected ecosystems and materials. Today, there are six ICPs, each headed by a lead country, organized by a task force and served by an international programme centre, and the Task Force on the Health Aspects of Air Pollution, established jointly by the World Health Organization (WHO) and the Executive Body. Their work proceeds in parallel with the atmospheric science work of EMEP and the work of the Working Group on Strategies and Review related to the potential needs for reviewing and revising existing protocols or for preparing new protocols.

6. The objective of this report is to present an assessment of the present status of air pollution effects and their recorded trends based, in large part, on long-term results of the work by the ICPs and the Task Force on Health of the Working Group on Effects. The report aims to provide the Executive Body with summarized and assessed effects-based data and information needed for the forthcoming review of the protocols to the Convention.

II. EVOLUTION OF THE EFFECTS-RELATED WORK OF THE CONVENTION

7. While effects of air pollution always were a major consideration in the development of protocols, the early protocols did not use effects to define Parties' obligations for emission reductions. For example, the 1985 Sulphur Protocol adopted a flat-rate approach; it established commitments by Parties to reduce their annual sulphur emissions by 30%. The 1988 Protocol on Nitrogen Oxides adopted a mix of measures. Parties would limit their nitrogen oxide emissions and apply best available technology to major new sources.

8. Large-scale cooperative monitoring networks were established by ICPs from the mid-1980s, building on existing national programmes, and provided systematic observational evidence for and insight into air pollution effects on various receptors.

9. Recognition that there might be opportunities to use effects more directly in setting emission targets was first included in the 1988 Protocol on Nitrogen Oxides. It stated that "further steps to reduce national annual emissions of nitrogen oxides" should take into account "internationally accepted critical loads", the deposition below which harmful effects on various ecosystems would not occur according to present knowledge (art.2).

10. Establishing critical loads required an important effort. A large number of scientific workshops and other expert meetings identifying pollution receptors and thresholds were held during the late 1980s and 1990s. A manual was developed to guide the Parties in using recommended methods to calculate and map critical loads in a harmonized manner. They were responsible for gathering their country-specific data.

11. Eventually, critical loads of acidity for forest soils and surface waters were compiled and mapped for Europe and so were their exceedances (the deposition which exceeds critical loads). Using integrated assessment models, a task force under the Working Group on Strategies and Review evaluated the results from integrated models using critical loads data in conjunction with meteorological information, emissions data and abatement costs. It produced a number of emission reduction scenarios to support negotiations for the 1994 Protocol on Further Reduction of Sulphur Emissions.

12. The 1994 Sulphur Protocol was the first effects-based instrument to set air pollutant emission controls for achieving the desired environmental protection at lowest costs for the countries involved. In contrast to the earlier protocols, it takes into account the ability of the environment to withstand certain levels of pollution while assigning to each country a different emission reduction target in the form of an emission ceiling.

13. Describing exceedances of critical loads of acidity (the excess deposition over the critical load) was developed to allow combinations of sulphur and nitrogen depositions. Critical loads for the eutrophying effect of nitrogen on terrestrial ecosystems were also derived. The formulations of critical loads were thus advanced to account for both acidifying and eutrophying effects simultaneously. In addition, critical levels of ozone for the protection of human health and plants were developed.

14. The effects-based approach was subsequently used for the 1999 Gothenburg Protocol, a multi-pollutant and multi-effect protocol. This Protocol simultaneously addresses acidification, eutrophication and ground-level ozone by setting emission ceilings for four pollutants: sulphur, nitrogen oxides (NOx), ammonia and volatile organic compounds (VOCs).

15. Two protocols to the Convention were adopted in 1998 to address air pollutants not covered by the earlier protocols. The 1998 Protocol on Heavy Metals addresses the environmental concerns associated with the long-range transport of heavy metals. It focuses initially on cadmium, lead and mercury, but includes provisions for adding other metals in future if considered necessary. The Protocol aims to cut emissions of the three priority metals from industrial sources, combustion processes and waste incineration. The 1998 Protocol on Persistent Organic Pollutants (POPs) aims to control the release into the environment of a number of pesticides, industrial chemicals (such as PCBs) or substances (such as dioxins) unintentionally formed in waste incineration and combustion processes. The Protocol lists 16 substances and includes provision for substances to be added or current obligations to be modified as new information is obtained. Neither of these two protocols uses an effects-based approach but work is under way to determine the feasibility of using a critical loads approach for some heavy metals.

III. STATUS AND TRENDS

A. Human health effects of air pollution

16. There is a large body of evidence suggesting that exposure to air pollution, even at the levels commonly achieved nowadays in European countries, leads to adverse health effects. In particular, exposure to pollutants such as particulate matter (PM) and ozone has been found to be associated with increases in hospital admissions for cardiovascular and respiratory disease and

mortality in many cities in Europe and other continents. In 2002, WHO estimated that close to 100,000 deaths annually are associated with long-term exposure to air pollution.

1. Particulate matter

17. There is strong evidence to conclude that fine particles (commonly measured as particulate matter < 2.5 µm, PM2.5) are more hazardous than larger ones (coarse particles) in terms of mortality and cardiovascular and respiratory effects. Fine particles are strongly associated with mortality and other effects such as hospitalization for cardio-pulmonary disease. There is sufficient concern also about the health effects of coarse particles to justify their control.

18. Epidemiological studies on large populations have been unable to identify a threshold concentration below which ambient PM has no effect on health. Even at the lowest end of the observed PM2.5 concentration range, some - the most susceptible - subjects are at risk.

19. Amongst the characteristics found to be contributing to the toxicity of particles are metal content, presence of polyaromatic hydrocarbons (PAHs), other organic components and the size fractions, both the small (< 2.5 µm) and extremely small size (< 0.1 µm). However, the Task Force on Health has concluded that it is not possible to quantify the relative importance of the main PM components for effects on human health at this stage.

2. Ozone

20. Recent epidemiological studies have strengthened the evidence that there are short-term ozone effects on mortality and respiratory morbidity. Also, there are effects related to long-term ozone exposure, e.g. reduced lung function growth in children.

21. There is little evidence from short-term epidemiological studies to suggest a threshold ozone concentration at the population level. Long-term studies do not indicate a threshold either.

3. Heavy metals

22. The Task Force on Health has reviewed information on the sources, chemical properties and spatial distribution of pollution from cadmium, lead and mercury, and has evaluated the potential health effects in Europe.

23. Food is the main source of cadmium exposure in the general population, responsible for about 99% of the total intake in non-smokers. Kidney and bone are the critical target organs following chronic environmental exposure to cadmium. There is strong evidence that, though the

atmospheric deposition is relatively small, cadmium is accumulating in soils and catchments under certain environmental conditions, thus increasing the risk of future exposure through food.

24. Soil and dust are significant sources of exposure to lead, particularly for young children. Children are the critical population due to the possible effects of lead on the neuro-behavioural development. Food uptake is the main pathway of exposure in the general population though the present environmental exposure to lead may be considered as relatively safe for adults. Present data on the concentrations of lead in air and estimates of the daily intake of lead with food suggest a decreasing trend of environmental lead exposure, in particular in countries where lead has been eliminated from petrol.

25. Long-range transboundary transport of anthropogenic mercury is a considerable contributor to mercury concentrations in the environment. However, estimating the risks from dietary exposure to mercury resulting from the deposition of mercury to soil is difficult to quantify. The mercury content in fish often exceeds the recommended limit in many countries.

4. Persistent organic pollutants

26. The Task Force on Health reviewed the health risks of POPs and identified those for which long-range transport contributed significantly to exposure and health risks. Furthermore, the Task Force on Health performed a brief hazard assessment for various POPs identifying the main gaps in information necessary for risk assessment.

B. Effects of air pollution on ecosystems

1. Surface waters

27. For surface waters, the ultimate goal of emissions controls is biological recovery, or the return of sensitive species that have been eliminated during the course of acidification. This will occur only when the water quality is sufficiently good. This is one reason for the focus of ICP Waters on chemical data. Another is that water chemistry data are much more readily available than biological data. Biological data are nevertheless required because ecosystems may not return to an earlier stage, but will reflect the present physical, chemical and biological environment.

28. The most significant finding in the regional trend analysis carried out by ICP Waters is the almost universal decrease in sulphate concentrations in lakes and streams in regions throughout Europe and North America. This result, based on 15 years of data, provides clear evidence of the environmental benefits resulting from SO_2 emission reductions. In contrast to sulphate, changes in nitrate concentrations are modest. Fewer than half of the regions exhibited a significant

regional trend – either increasing or decreasing. The combined result of the decrease in sulphate and the modest changes in nitrate is that surface water acidity has generally been reduced.

29. Evidence of a biological response to decreased surface water acidification is, so far, not uniform throughout the study area. Signs of recovery are observed for invertebrates in the Scandinavian countries and in Canadian lakes formerly affected by a large local emission source, while at the most acidified Central European sites improvements in water quality have not yet reached a level where widespread effects on biology can be detected.

30. Predictions, both by steady-state and dynamic models, indicate that surface water chemistry will continue to improve. Comparing the nitrogen and sulphur depositions in 1990 to site-specific critical loads of acidity for 72 European ICP Waters sites shows that there were exceedances at 51 of the sites. Implementation of current emission reduction plans reduces to 32 the number of the sites still expected to have exceedances in 2010. Dynamic models predict the site-specific timescale of the recovery.

31. Nitrogen deposition remains a concern. About half of the ICP Waters sites exhibit a high degree of nitrogen saturation. The 1999 Gothenburg Protocol will slow down the process, but nitrogen will continue to accumulate in terrestrial ecosystems and thus increase the risk of saturation in the long term.

2. Forests

32. Forest condition in Europe has been deteriorating for more than two decades. Studies in the early 1980s revealed widespread forest damage across Europe. At that time, media reports of predictions of a large-scale forest dieback due to air pollution generated grave concern among the general public. More than two decades of forest damage research and 17 years of monitoring forest condition in Europe have since led to a more differentiated view; recent forest damage is explained by means of synergistic effects of a range of natural and anthropogenic factors with air pollution playing a predisposing, accompanying and locally triggering role.

33. Defoliation is used as an indicator for numerous environmental factors affecting tree vitality. The assessment of the trends in crown condition, since 1986, at some 6000 sample plots of the level I programme (large-scale monitoring) by ICP Forests has revealed a clear overall increase in defoliation. After a transient recuperation in recent years, the deterioration now seems to be resuming. This overall trend, however, shows high spatial and temporal variation.

34. Chronic excess input of nitrogen to forest ecosystems causes nutrient imbalances which, in turn, increase the sensitivity of plants to climatic factors, such as frost or drought, and susceptibility to parasite attacks. Approximately half of 109 ICP Forests level II plots showed

nutrient imbalances. The plots are part of the ICP Forests level II network of 860 intensive monitoring sites but not all the sites have all the data necessary to check for nutrient imbalances. The results are consistent with results from a modelling study of approximately 230 ICP Forests level II sites which concluded that at 45% of sites nitrogen deposition was sufficient to cause nutrient imbalance. The same study concluded that nitrogen deposition at 92% of the sites was such that nitrogen would continue to accumulate in the soils, thus moving the ecosystems toward nitrogen saturation in the long term.

3. Vegetation

35. Field surveys and bioindicator studies have provided important evidence for the significance of ozone as a phytotoxic pollutant across Europe. ICP Vegetation has been monitoring the frequency of incidences of ozone injury on ozone-sensitive species each spring and summer since 1994. Ozone injury has been recorded at every site in the network of 35 sites across Europe and 2 sites in the United States most years and several times per year at many of the sites. Ozone injury was also detected on the foliage of over 20 agricultural and horticultural crops, including on crops such as lettuce, chicory and spinach for which such foliar damage results in loss in commercial value. At many of the ICP Vegetation biomonitoring sites, participants have also detected a reduction in the biomass of a sensitive biotype of white clover, relative to that of a resistant biotype. No trends in incidences of injury or biomass change have been detected, possibly reflecting the large year-to-year variation in ozone pollution.

36. For crops and forest trees, exposure indices that provide a more biologically realistic representation of the exposure of plants to ozone than indices that are based on ozone concentration only were developed. The new exposure indices take into account the influence of humidity on the uptake of ozone by the plant. This is important because, for a given ozone concentration, ozone uptake in dry air can be much less than that for the same plants exposed to ozone on a humid day. The new indices are used to improve estimates of critical levels. Unlike concentration-based critical levels, the new relationships between yield and ozone uptake can be used to estimate yield loss.

37. The analysis of heavy metal concentrations in mosses provides a surrogate, time-integrated measure of the spatial patterns of heavy metal deposition from the atmosphere to terrestrial systems, and is easier and cheaper than conventional precipitation analysis. The ICP Vegetation heavy metals in mosses survey provides data on concentrations of ten metals (arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, vanadium, zinc) in naturally growing mosses throughout Europe. The resulting maps show an east-to-west decrease in metal concentrations in mosses, related in particular to industrial emissions. Former industrial sites and historic mines accounted for the location of some high concentrations in areas without contemporary industries. Long-range transboundary transport appears to account for elevated

concentrations of heavy metals in areas without local emission sources, such as lead in Southern Scandinavia. A preliminary comparison of the 1995 and 2000/2001 surveys indicates a general decline in the concentrations of arsenic, cadmium, lead and vanadium in mosses.

4. Integrated monitoring of ecosystems

38. The ICP Integrated Monitoring network of approximately 50 sites in Europe and one in Canada has been set up especially to understand the dynamics and processes of ecosystem changes, and thus to determine the causes of the changes. It provides inputs for the development, testing and calibration of dynamic models. The data, when used in conjunction with data sets from the more regionally extensive ICPs, provide an integrated hierarchical structure for evaluating the impacts of air pollutants on the European scale. The ICP Integrated Monitoring data are used to better understand acidification, eutrophication and other nitrogen-related effects, as well as the cycling and effects of heavy metals in ecosystems.

39. Input-output budget calculations carried out at ICP Integrated Monitoring sites inform about possible accumulation or release of sulphur, nitrogen, base cations and aluminium in the ecosystem. Calculations for 21 ICP Integrated Monitoring sites in Europe indicate that soils at these sites are recovering from high sulphur inputs in the past by releasing more sulphate than they currently receive. The calculations also document the production of acidity related to the deposition and cycling of nitrogen at the sites.

40. Long-term data sets of observations at ICP Integrated Monitoring sites were used to test the performance of dynamic models and improve them. Model simulations, based on these data sets, indicate that recovery of soil and water quality from acidification is determined by both the amount and the time of implementation of emission reductions. Extending the target year for emission reductions causes a delay in the ecosystem recovery in the shorter term (less than 30 years). For the long-term response, the magnitude of emission reductions is more important than the timing of the reduction. Model development is still needed regarding several key processes, particularly nitrogen dynamics and relations to climate change.

41. For many decades, large regions of North America and Europe have received elevated deposition of nitrogen compounds. ICP Integrated Monitoring sites improve our understanding of the nitrogen cycle and predictions of long-term effects of chronic excess nitrogen deposition.

C. Effects of air pollution on materials

42. Materials selected for study by ICP Materials are representative of both technical materials and also materials used in objects of cultural heritage. They include metallic materials, stone, paint coatings, electric contact materials, glass and polymeric materials.

43. Reductions of corrosion rates for many materials observed in the period 1987-1995 at 39 sites have been in the order of 30-70%. They are a result of the decrease in sulphur dioxide concentrations in ambient air during the same period. In the past this pollutant has been the dominating factor causing degradation to materials and objects of cultural heritage. Recent data show a break in the decreasing corrosion trend, with no evident further decrease for more and more sites. This is because the corrosion is due not only to SO_2 but also to a mixture of sulphur and nitrogen compounds, ozone and particulate matter. This multi-pollutant situation is also the reason for the corrosion rates in urban areas being considerably higher than those in surrounding rural regions. The corrosion rate in central Stockholm, for example, was about three times higher than at the rural site in Aspvreten, situated 80 km to the south-east.

44. The eight-year dose-response functions – developed by ICP Materials - are, at present, the best available functions to use for mapping procedures on both national and European scales. A number of countries have produced maps of the increased risk of corrosion to materials using these functions. Also, an approach similar to the critical levels approach has been developed in order to use the functions for setting emission targets. Calculations have been made, for example, to determine what levels of SO_2 would be required in order to maintain corrosion rates at 1.5 times (or twice) the background corrosion rate. The resulting "acceptable levels" of SO_2 for several of the materials are quite low compared to critical levels for most ecosystems and human health.

45. Case studies have shown that there is a substantial release of some metals (e.g. copper and zinc) to the biosphere as a result of weathering and especially due to acidifying pollutants. Metal release to the environment was quantified in countries where stock of materials at risk was available.

D. Modelling and mapping of air pollution effects and risks

46. European databases of critical loads and levels used to support effects-based protocols were compiled by ICP Modelling and Mapping with contributions of national data from Parties' national focal centres, and scientific and technical support from the Coordination Center for Effects (CCE). The analysis of exceedances using the database used to support the 1999 Gothenburg Protocol predicted that, after implementation of the Protocol, both the magnitude of exceedances and their geographical extent would be substantially less than in 1990 for acidity, but less pronounced for nutrient nitrogen. The ultimate goal of non-exceedance would not be reached in large parts of Europe.

47. The European databases of critical loads of acidity and of nutrient nitrogen were updated in 2003/2004. Generally, the new values have not changed substantially from the ones that were used in 1999. The new maps of exceedances, however, show higher remaining exceedances in

2010 than expected in the original assessment for the 1999 Gothenburg Protocol. These exceedances are mainly due to an improved deposition model, the finer resolution of the EMEP grid and the use of ecosystem-dependent deposition.

48. Updating the concentration-based critical levels of ozone for agricultural crops, semi-natural vegetation and forest trees, and using a more biologically realistic representation of the exposure of crops to ozone, also provide improved estimates of the projected exceedances of critical levels of ozone after full implementation of the Protocol.

49. For the first time, in 2003, the European database of critical loads of acidity was extended to include parameters needed for dynamic modelling. Dynamic models provide information on time delays of ecosystem damage – or recovery – caused by changes in acidifying deposition. A very simple dynamic model is being proposed for application at the European scale. First tests have shown the need to improve the performance at the European level. Linking dynamic models and integrated assessment models requires information about "target years", i.e. the timeline for environmental goals to be met.

50. A series of workshops under the Convention in the past decade have contributed to improving methodologies to derive critical limits and critical loads of heavy metals, in particular lead, cadmium and mercury, for terrestrial and aquatic ecosystems. A study in 2002 in several European countries showed that the aim of producing maps of critical loads and their exceedances was not unrealistic. After further improvement of the methodology, European maps of critical loads and their exceedances could be produced by 2005.

IV. CONCLUSIONS

A. Monitoring has exposed the extent of effects of air pollution

51. Monitoring shows that air pollution causes widespread damage in Europe and North America: long- and short-term effects on human health, acidification of surface waters and soils, effects on forest health and productivity; eutrophication; plant injury and reduced productivity of crops; accelerated corrosion and soiling of materials. Work by ICPs and the Task Force on Health has documented the extent and severity of damage, and in some cases, of the first signs of recovery.

B. Monitoring reveals the start of recovery in some areas

52. This is particularly evident in terms of improvements in surface water quality, specifically related to an almost universal decrease in sulphate concentrations in lakes and streams. These improvements have led to isolated signs of biological recovery but improvements in water quality

have not yet reached a level where widespread effects on biology can be detected. In addition, the reduction in corrosion rates for many materials (in the order of 30-70% during the period 1987-1995) is also attributed to a reduction in sulphur dioxide emissions.

C. Recent results strengthen and refine the scientific basis for the protocols

53. Better data, models and improved dose-response relationships provide a stronger scientific basis for predicting environmental effects, risks and trends, and increase the level of confidence in earlier predictions that air pollution control measures will produce further benefits for sensitive ecosystems and for human health. Such predictions are particularly useful to anticipate continuing problems in slow-reacting ecosystems, e.g. forests and the soils on which they grow.

D. There are still threats

54. Threats related to acidification, eutrophication, ozone, heavy metals and POPs will all be reduced as a result of the existing protocols being implemented. Nevertheless, some problems will remain:

(a) Acidification: steady-state as well as dynamic model predictions indicate that additional measures are required to protect all sensitive ecosystems from acidification;

(b) Eutrophication: many ICP Forests plots show signs of nutrient imbalance and elevated leaching of nitrate. Similarly, half of the ICP Waters sites exhibit a high degree of nitrogen saturation. The measures in the 1999 Gothenburg Protocol will ease the problem. Nevertheless, the current commitments are insufficient to prevent further accumulation of nitrogen in ecosystems over the long term;

(c) Ozone and PM: Current levels of ozone as well as levels of fine particles in many European and North American cities still lead to adverse health effects. Also, due to the multi-pollutant environment in urban centres, materials - whether technical materials or materials used in objects of cultural heritage – corrode faster and are soiled more rapidly than in the surrounding rural regions. Current levels of ozone also affect crops, forest trees and semi-natural vegetation over most of Europe and North America;

(d) Heavy metals: though emissions of lead, cadmium and mercury have been cut, these metals are expected to continue to accumulate in soils and reach concentrations sufficient to affect biota. The cadmium content of agricultural soils is also of concern because of its possible effects on human health.

E. More sophisticated models and approaches are available for use

55. More sophisticated models and approaches are available for use, including:

(a) Moving from steady-state to dynamic modelling of acidification processes enables consideration of the time element in the policy process. Dynamic models and the related target loads provide information on the time for ecosystems to acidify or recover, and this can be used to set environmental goals and the corresponding air pollution control measures;

(b) For human health, better assessment of exposure to ozone and PM; for vegetation, flux-based exposure indicator and better representation of the risk of damage due to exposure to ozone. These all provide better evaluation of environmental and health benefits of control measures;

(c) Methodologies that have been developed, and are being improved, to use the critical loads approach for selected heavy metals.

56. These advances are available for use within the Convention and in wider international forums.

F. The effects-based approach is an effective way of meeting environmental goals

57. The process of combining data on critical loads, emissions, meteorological information and pollution abatement costs has allowed Parties to the Convention to optimize emission reductions to meet environmental goals at the lowest total cost. The scientific community is confident that what has worked well for the 1994 Sulphur Protocol will work well also for the 1999 Gothenburg Protocol, i.e. meeting the emission ceilings for SO_2, NOx, ammonia and VOCs will further reduce damage caused by acid deposition, reduce or prevent damage due to eutrophication and ground-level ozone.

G. There has been useful interaction between science and policy

58. Study of the effects of air pollution has always been a major driving force for the work of the Convention. Using effects more directly in policy development has had major benefits for both policy and science but has led to the need for close interaction between the two. The resulting improvements in knowledge have been successfully applied in national and international programmes to reduce air pollution.

H. Convention-wide participation is important

59. Parties participating in the scientific monitoring, research and modelling programme contribute the essential data that underpin the work of the Convention. ICPs and Task Forces – with support from their lead countries - provide the vital coordination, assistance and direction to the scientific effort. The Working Group on Effects reviews results annually, ensures that they are communicated effectively and agrees on its future programme of work.

V. CHALLENGES

60. The work under the Convention has gained wide acceptance mainly because it has been based on the best available scientific knowledge. Further progress requires uncertainties to be reduced in important areas such as: the understanding of nitrogen cycles and the effects of chronic elevated nitrogen deposition; the effects of PM and ozone on human health; biological recovery from acidification; the material effects in a multi-pollutant environment; and the combined effects of air pollutants together with the possible effects of climate change. Assessing whether pollution abatement measures are having their desired effect requires an ongoing commitment to long-term monitoring.

61. The international scientific effort carried out under the aegis of the Convention should continue. It has played a vital role in developing the scientific foundation for the work under the Convention and it is required to monitor and assess future progress resulting from implementation of the protocols as well as to provide information for their review and possible revision. It is through international cooperation and coordinated effort that innovative approaches were developed and adopted, and that Convention-wide databases on air pollutant effects were built. Parties are urged to continue their involvement through their domestic scientific programmes, through active participation by their experts and through their support for the ICPs and Tasks Forces, whose importance in coordinating the international effort is vital. Parties have played a key role in developing the effects-related work to a point where it contributes directly to policy decisions and provides the potential to contribute their input in the future too.