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Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe

Working Group on Effects

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Item 3 of the provisional agenda
Progress in activities of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe in 2019 and future work

2019 joint progress report on policy-relevant scientific findings*

Note prepared by the Chairs of the Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe and the Working Group on Effects, in cooperation with the secretariat

Summary

The present report was drafted by the Extended Bureau of the Working Group on Effects[1] and the Extended Bureau of the Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP)[2] in cooperation with the secretariat to the Convention on Long-range Transboundary Air Pollution. The review of recent scientific findings is based on the information provided by the lead countries and the programme centres of the international cooperative programmes, and is submitted in accordance with the 2018–2019 workplan for the implementation of the Convention (ECE/EB.AIR/140/Add.1).

* The present document is being issued without formal editing.

[1] Comprising the Bureau of the Working Group; the Chairs of the international cooperative programme task forces, the Joint Task Force on the Health Effects of Air Pollution and the Joint Expert Group on Dynamic Modelling; and representatives of the programme centres of the international cooperative programmes.

[2] Comprising the Bureau of the Steering Body, the Chairs of the EMEP task forces and representatives of EMEP centres.

Contents

I. Introduction

1. The present report was compiled by the Chairs of the Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP) and the Working Group on Effects in accordance with the 2018–2019 workplan for the Convention on Long-range Transboundary Air Pollution (ECE/EB.AIR/140/Add.1). The report reflects achievements during 2018 and 2019 and was prepared with support from the scientific subsidiary bodies. The report is the forth common report of the work under EMEP and the Working Group on Effects, reflecting the new organization of the two bodies with joint, integrated sessions based on a common agenda. These joint reports represent a further integration of the scientific work under the Convention and should be seen as a strengthening of the scientific basis for the Convention's policy development.

II. Air pollution effects on health

2. The Task Force on Health Aspects of Air Pollution is a joint body of the Executive Body and the World Health Organization (WHO), led by the WHO European Centre for Environment and Health (Bonn, Germany), responsible for evaluating and assessing the health effects of long-range transboundary air pollution and providing necessary information in the field.

3. Initiated in 2016, the process of the update of WHO global air quality guidelines continues. It aims to provide updated numerical concentration values and, where possible, an indication of the shape of the concentration-response function, for a number of ambient air pollutants, for relevant averaging times and in relation to critical health outcomes. The air pollutants included are: particulate matter (PM2.5, PM10), nitrogen dioxide (NO2), ozone (O3), sulphur dioxide (SO2) and carbon monoxide (CO). Commissioned in 2017, five core systematic reviews of evidence on health effects from air pollution are have been completed and are subject to peer review, focusing on:

(a) Long-term exposure to PM, O3 and NO2 and all-cause and cause-specific mortality;

(b) Short-term exposure to O3, NO2 and SO2 and emergency department and hospital admissions due to asthma;

(c) Short-term exposure to PM, NO2 and O3 and all-cause and cause-specific mortality;

(d) Short-term exposure to CO and emergency department and hospital admissions due to ischaemic heart disease.

4. After the completion of the systematic reviews of evidence and most methodological adaptations, the second phase of the update of WHO global air quality guideline process is about to start, to derive numerical guideline exposure values, set interim targets and formulate recommendations. The third meeting of the Guideline Development Group, in June 2019, provided an opportunity to assess the systematic reviews and to discuss the methodology for deriving guideline exposure values, as well as for setting interim targets.

5. In 2019, the WHO Regional Office for Europe convened an expert meeting to strengthen the knowledge base on the critical issues around the health impact assessment of NO2 in the European context, taking into account new research and the relevant experiences from the Member States of the European Region. Experts discussed these issues in the wider context of updating the methodology for calculating the health impact of air pollution, and for considering NO2 in future health impact assessments. The results of this meeting will contribute to future work towards revising the concentration response functions and methods for health impact assessment in Europe.

III. Air pollution effects on materials

6. The International Cooperative Programme on Effects of Air Pollution on Materials, including Historic and Cultural Monuments (ICP Materials) activities are currently conducted in the scope of the Call for data on the Inventory and condition of stock of materials at the United Nations Educational, Scientific and Cultural Organization (UNESCO) cultural world heritage sites launched in October 2015 and which involves Croatia, Germany, Italy, Norway, Sweden and Switzerland. First results were compiled in ICP Materials Report No 83.[3]

7. The main risk factors (pollutants) for the different risks (corrosion/soiling) are summarized in Table 1. Particulate matter (PM10) was identified as a risk factor both for corrosion and soiling of limestone while nitric acid (HNO3) was identified only for corrosion. The combined effect of SO2 and O3 was identified as a risk factor for copper, and PM10 and NO2 were identified as risk factors for soiling of glass. SO2 is still an important deterioration agent for some materials used in cultural heritage but no longer the dominant factor. Also, the acidity of precipitations seems to have a small impact on the degradation of materials in the current situation.

Table 1
Risk factors (pollutants) for different risks to materials constituting the artifacts (+ low impact; ++ medium impact; +++ high impact). An empty square indicate that the specific risk/pollutant combinations was not included in the used dose-response function. Therefore, the impact level could not be estimated.

Risk	SO_2	NO_2	HNO_3	SO_2*O_3	PM_{10}	*pH*
Limestone corrosion	+/++		++/+++		++	+
Sandstone corrosion	+/++					+
Copper corrosion				++/+++		+
Bronze corrosion	+				++	+
Limestone soiling					+++	
Glass soiling	+/++	++/+++			++/+++	

8. At current concentrations of air pollutants, recession of limestone, corrosion of copper and soiling of both non-transparent (limestone) and transparent (glass) artefacts could be an issue for several historic and cultural monuments. Estimated recession rate of limestone and corrosion rate of copper after one year of exposure were well above the background corrosion rate (3.2 µm year-1 for limestone and 0.32 µm year-1 for copper) and generally close to the target set by ICP Materials for the year 2050 (twice the background corrosion rate) or even higher. In some cases, these values are close to the targets set for 2020 (2.5 the background corrosion rate). Soiling of limestone and glass artifacts appears unacceptably high.

9. At the thirty-fifth meeting of the ICP Materials Task Force (Paris, France, 24–26 April 2019) the evaluation of the expected cost of the damage due to air pollution was discussed. On the basis of preliminary data, annual cost of damage attributable to air pollution, depending on the pollution level and the meteo-climatic conditions, for the twenty-one cultural objects assessed range from € 3.1 to € 20 per square meter of surface (€ m-2 year-1) for the recession of limestone, from 5.1 to 9.8 € m-2 year-1 for the corrosion of copper, from 0 to 52.1 € m-2 year-1 for the soiling of limestone surfaces and from 0 to 11.7 € m-2 year-1 for the soiling of glass. These costs add to the cost in background areas, estimated in 4.4 € m-2 year-1, 3.5 € m-2 year-1, 25 € m-2 year-1 and 6.8 € m-2 year-1, respectively, for limestone recession, copper corrosion, limestone soiling and glass soiling.

[3] ICP Materials Report No 83: Call for Data “Inventory and condition of stock of materials at UNESCO World Cultural Heritage sites, 2015-2017”. Part II-Risk assessment).

IV. Air pollution effects on terrestrial ecosystems

A. Forests: Air pollution still a threat for sensitive elements

10. In the period 2000 and 2014, the ozone concentrations decreased significantly at the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) sites by 0.63 ppb/a. The long-term mean ozone concentration in the growing season (April – September) in that period was 36.2 part per billion (ppb). Values ranged from 14.5 ppb to 70.1 ppb showing a marked north- south gradient across Europe with highest concentrations in Italy, Southern Switzerland, Czechia, Slovakia, Romania and Greece. Despite the reduction in ozone concentrations, ozone levels still exceed the threshold value for adverse effects in 13 out of 15 countries. Direct effects of ozone exposure are apparent in terms of foliar visible symptoms and have been observed on woody plant species all across Europe. However, the relationship between ozone exposure and visible symptoms is not straightforward, but depend on species-specific sensitivity, nutrition, water availability and climate.

11. The spatial distribution of yearly throughfall deposition of nitrate and ammonium collected in 248 ICP Forests Level II plots and 49 SWETHRO (the Swedish Throughfall Monitoring Network) plots across Europe in 2017 shows a marked spatial variability of atmospheric deposition. However, on a broader scale, regional patterns in throughfall deposition arise. In the case of nitrate, high throughfall deposition was mainly found in Central Europe: Germany, Switzerland, Czechia, Austria and Flanders, while values below 4 kg N ha^{-1} y^{-1}, were mainly found in Finland, Sweden, Norway, Hungary, Bulgaria, Romania, Latvia and Estonia. The Central European area of high ammonium throughfall deposition is larger, also including North Italy, Southwest United Kingdom, South Romania, and west Poland. Values below 4 kg N ha^{-1} y^{-1}, were found again in Norway, Sweden, Finland, Bulgaria, Latvia, and Estonia, but also in parts of France, Austria and Slovakia. Note that the total nitrate and ammonia deposition to the forest can be higher than the throughfall deposition, due to canopy exchange processes. Nitrogen (N) compounds have two effects on the ecosystems: they are important plant nutrients with strong effects on plant metabolism, all forest processes, and biodiversity, but they can also reinforce soil acidification. It is well known that enhanced deposition of nitrogen, atmospheric carbon dioxide (CO_2) enrichment as well as warmer temperatures and longer growing seasons have stimulated tree growth in many parts of Europe. These increases in tree growth lead to an increasing nutrient demand. If and to what extent nitrogen excess results in nutrients imbalances is currently under investigation. To this end, the ICP Forests long-term data set (469 plots from 26 countries) on nutrient contents of tree foliage is analysed.

B. Forested catchments

12. It is for long recognised that forests are dynamic systems at all stages of succession, that disturbance at different scales plays a key role in their development. Given that the frequency and severity of natural disturbance agents is predicted to increase under conditions of global change, there is a pressing need for a greater understanding of how the combined effects of anthropogenic background disturbances and natural disturbance cycles may impact thus-far resilient ecosystems. The International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems (ICP Integrated Monitoring), therefore, carried out a literature review on the resilience in forest ecosystems to different disturbance factors.4

[4] James Weldon "Post disturbance vegetation succession and resilience in forest ecosystems – a literature review", in Sirpa Kleemola and Martin Forsius, eds., *27th Annual Report 2018: Convention on Long-range Transboundary Air Pollution. International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems*, Reports of the Finnish Environment Institute, No. 20 (Helsinki, 2018), pp. 39-52, available at http://hdl.handle.net/10138/238583

13. All forests, even unmanaged semi-natural forests, are subject to diffuse anthropogenic disturbances such as eutrophication and acidification via atmospheric deposition of N and sulphur (S), and climate change, which have the potential to result in a loss of biodiversity and changes in vegetation community composition5, negatively impacting forest resilience to future disturbance. While much progress has been made in reducing S emissions linked to damaging "acid rain", levels of N deposition remain stubbornly high and are of growing ecological concern. It is thus an open question whether forests can continue to manifest resilience to natural disturbances when additionally stressed by such diffuse anthropogenic disturbance factors, and if so for how long.

14. The extensive literature review concluded that disturbance regimes and associated patterns of regeneration and succession are important parts of forest dynamics and can help to foster biodiversity and resilience. However, the additional stresses placed on forest ecosystems by diffuse anthropogenic impacts act to reduce that resilience. Numerous experimental studies have shown that N inputs are capable of causing major changes in forest vegetation and some recent studies have provided evidence that ongoing N deposition is indeed changing understory vegetation and affecting canopy growth. The combined effects of N deposition then, are likely to result in lower forest resilience in ecosystems simultaneously facing an increased frequency and/or intensity of natural disturbances including storm damage and outbreaks of bark beetles. Such disturbance interactions can have unpredictable and surprising consequences which are as yet insufficiently studied, and sites that have experienced severe combined perturbations may show evidence of regime shifts. Long-term monitoring and research is thus needed to document such complex patterns.

C. Temporal trends of heavy metal and nitrogen concentrations in mosses

15. According to the monitoring done under the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops (ICP Vegetation), between 1990 and 2015, lead and cadmium concentrations in mosses have declined by 81 per cent and 64 per cent respectively. Concentrations of other heavy metals (arsenic, chromium, copper, iron, nickel, vanadium and zinc) have declined too, ranging from 9 per cent for chromium to 58 per cent for vanadium. Concentrations of mercury in mosses, however, have not changed since 1995. Nitrogen concentrations in mosses have not changed significantly either between 2005 and 2015. In 2015, generally the highest heavy metal concentrations in mosses where found in eastern and south-eastern Europe; the highest nitrogen concentrations in mosses were generally observed in central Europe, including Germany, Romania and Slovakia.

V. Air pollution effects on aquatic ecosystems

16. Preliminary results from the upcoming 2019 report on trends in surface water chemistry showed that sulphate and base cations have decreased while Acid Neutralising Capacity (ANC), pH and dissolved organic carbon (DOC) have increased at many of the sites since 1990. Trends for nitrate were more mixed. For Europe most change points for sulphate, base cations and ANC were detected just before 2000, while for DOC they appeared almost a decade later. Trends in severity of events as well as effects of land use on recovery will also be included in the report. These regular trend reports are important to identify where, and for which parameters, recovery from acidification is or is not satisfactory.

17. A study of two neighbouring lakes in the Lake District of the United Kingdom highlights the importance of buffering capacity for the recovery from acidification. In southern Finland, forestry, as well as beaver activity, influenced the long-term water chemistry trends in small boreal lakes. In Czechia, long-term monitoring data and dynamic modelling showed that although a major bark beetle attack caused a short-term halt in recovery from acidification, decomposition of biomass and vegetation regrowth accelerated

[5] Thomas Dirnböck and others, "Forest floor vegetation response to nitrogen deposition in Europe", in *Global Change Biology* 20 (2014): 429-440. https://doi.org/10.1111/gcb.12440.

recovery from acidification of both soil and water in the long-term. Land use and extreme events may thus have contrasting and surprising consequences, and it is important to increase the understanding of effects of such confounding factors on recovery from acidification.

18. The 2018 report on the current extent of acidification in Europe and North America[6] highlighted the lack of a harmonised approach to assessment of chemical acidification status, also under the European Union Water Framework Directive. In a Nordic project, classification of sites from Finland, Norway and Sweden and according to the different national systems showed marked differences, especially for brown waters. In a parallel exercise, correlating acidification parameters with benthic invertebrate data, ANC corrected for organic acids appears to be the most promising acidification indicator. Harmonisation of national systems for assessments of surface water acidification would lead to more consistent evaluations of surface water acidification, but care must be taken to preserve the level of accuracy of the individual assessment systems.

19. The benthic invertebrate communities of many European freshwaters are currently recovering as a response to reduced acid deposition. The change in species composition can alter the composition of functional traits in the biological communities. The functional traits have direct consequences for ecosystem health and for ecosystem services, such as litter breakdown, water filtering and nutrient spiralling.

20. The fish mercury (Hg) database collated under the International Cooperative Programme on Assessment and Monitoring of the Effects of Air Pollution on Rivers and Lakes (ICP Waters) is a valuable source of information for continued monitoring of impacts of Hg in the environment. In particular, lakes that are primarily impacted by atmospheric sources of Hg will be relevant for documentation of effects of reduced air pollution on fish Hg. In lakes where Hg originated mainly from long-range transboundary air pollution, consistent Hg declines (3–7‰ per year) were found for perch and pike in both boreal and subarctic Fennoscandia, suggesting common environmental controls. Future fish Hg monitoring sampling design should include repeated sampling and collection of pollution history, water chemistry, fish age, and stable isotopes to enable evaluation of emission reduction policies.[7] [8]

21. Georgia is expanding the lake and river monitoring network and has a new laboratory for water chemistry analysis. The main pressure on surface waters is untreated waste-water, but agriculture and industry also pose challenges to Georgia's water resources. A study in the Valday region of the Russian Federation showed higher heavy metal concentrations in precipitation in forested than open areas.

VI. Critical loads and levels

22. The International Cooperative Programme on Modelling and Mapping of Critical Levels and Loads and Air Pollution Effects, Risks and Trends (ICP Modelling and Mapping) has been in a transition period in 2018 following the changes of the country hosting the Coordination Centre for Effects (CCE) and the chairing person. The CCE is now hosted by Germany. The ICP Modelling and Mapping chairmanship is still hosted by France.

23. The call for data for critical loads on acidification, eutrophication and biodiversity (from 2015 to 2017) has been extended to February 2019. This call enabled Parties to update their data in the European critical loads database. Fourteen Parties to the Convention, all European Union member States, submitted updated critical loads for acidification and eutrophication, while six Parties embarked on the compilation and submission of critical loads of biodiversity. National Focal Centres (NFCs) provided most of the data for "Woodlands and Forests" (European Nature Information System class G) followed by

[6] Austnes et al 2018. Regional assessment of the current extent of acidification of surface waters in Europe and North America. NIVA report SNO 7268-2018. ICP Waters report 135/2018.

[7] Braaten et al 2019. Improved Environmental Status: 50 Years of Declining Fish Mercury Levels in Boreal and Subarctic Fennoscandia. *Environmental Science & Technology***,** *53*, (4), 1834-1843.

[8] UN Environment -2019. Global Mercury Assessment - 2018. UN Environment Programme Chemicals and Health Branch Geneva Switzerland. ISBN 978-92-807-3744-8.

"Grasslands, Forbs, Mosses and Lichens" (European Nature Information System class E). The CCE also started the process of rebuilding and updating the European Background Database. The European Critical Load dataset of the year 2015 – 2017, which can be used to support European air pollution abatement policies, is still valid and available for further work until the new CCE has not completed the new one (based on the 2019 NFC contributions) and as long as the new dataset has not been approved for use by the ICP Modelling and Mapping and the Working Group on Effects. Furthermore, CCE is working on the Web Map Service (WMS) in order to make the Critical Loads maps accessible on the CCE homepage. A new website has been launched already, providing general information on the ICP Modelling and Mapping, data and models, publications, as well as the initial and last version of the Mapping Manual. It can be reached at the following address: https://www.umweltbundesamt.de/en/Coordination_Centre_for_Effects.

24. New scientific information on effects of nitrogen has become available in the last years and has been presented at the thirty-fifth Task Force meeting. It enables ICP Modelling and Mapping to further update steady-state modelling and critical loads for biodiversity methodologies. A review process will be launched on empirical Critical Loads. Further methodological development will be carried out together with the Joint Expert Group on Dynamic Modelling, other ICPs, EMEP, experts and monitoring groups outside the Convention. The schedule of the ICP Modelling and Mapping activities will, as much as possible, be adapted to the timeline of the review of the amended Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (Gothenburg Protocol; 2022).

A. Critical Loads: Dynamic modelling

25. European databases and maps of critical loads have been instrumental in the negotiation of effect-based Protocols to the Convention. However, because the critical load concept is based on steady-state approach, dynamic models are needed in order to assess the timescale of impacts and recovery from changes in air pollutant emissions. Interaction with changes in climate variables is also of key importance. Current climate warming is expected to continue in the coming decades and the current high levels of N deposition may stabilise, in contrast to the clear decrease in S deposition. The timescale over which these improvements will affect ecosystems is, however, uncertain. These pressures have distinctive regional patterns and their impact on ecosystem conditions is modified by local site characteristics.

26. In order to assess benefits of currently legislated N deposition reductions on forest understory vegetation, 23 European forest sites belonging to the ICP Integrated Monitoring, ICP Forests and the Long-Term Ecosystem Research in Europe (eLTER) networks with high quality long-term data on deposition, climate, soil chemistry, and understory vegetation were studied. A dynamic soil model (VSD+) coupled to a statistical plant species niche model (PROPS) was applied with site-based climate and deposition9. The expected decrease in N deposition under current legislation emission (CLE) reduction targets until 2030 did not result in a release from eutrophication.

27. It can thus be concluded that that long-term research and monitoring sites are reference systems for developing and validating ecological models. Environmental policies may increasingly take advantage of infrastructures such as ICP Integrated Monitoring and the eLTER Research Infrastructure10, 11 and of the integrated ecosystem models they are

[9] Thomas Dirnböck and others, "Currently legislated decreases in nitrogen deposition will yield only limited plant species recovery in European forests", in *Environmental Research Letters* 13 (2018) 125010. https://doi.org/10.1088/1748-9326/aaf26b.

[10] Maria Holmberg and others, "Modelling study of soil C, N and pH response to air pollution and climate warming using European LTER site observations", in Science of the Total Environment 640–641 (2018): 387–399. https://doi.org/10.1016/j.scitotenv.2018.05.299.

[11] Michael Mirtl and others "Genesis, goals and achievements of Long-Term Ecological Research at the global scale: A critical review of ILTER and future directions", in *Science of the Total Environment* 626 (2018): 1439–1462. https://doi.org/10.1016/j.scitotenv.2017.12.001.

enabling. The results also showed that oxidized and reduced N emission reductions need to be considerably greater to allow recovery from chronically high N deposition. Legislative efforts should also focus on limiting N saturation in parts of the world, that have so far avoided the extreme amounts of cumulative N deposition that have occurred across large areas of Europe.

B. Critical Levels: Effects of ozone on vegetation

Impacts of ozone on wheat yield in Europe: modelled trends for 1990 – 2010

28. In collaboration with the European Topic Centre on Air Pollution and Climate Change Mitigation of the European Environment Agency, the ICP Vegetation contributed to an assessment of the trends of ozone impact on wheat yield in Europe between 1990 and 2010, using both concentration (AOT40[12]) and flux-based (POD_6SPEC[13]) metrics.

29. Based on the modelled AOT40, calculated wheat yield losses declined significantly from 18.2 per cent to 10.2 per cent between 1990 and 2010, whereas according to the flux-based metric losses did not change significantly, i.e. losses were 14.9 per cent and 13.3 per cent in 1990 and 2010, respectively. Compared with EMEP measured data, the downward trend of AOT40 is overestimated by the models (Eurodelta-Trends ensemble of six chemistry transport models), especially for the 1990–2000 decade. A change in ozone profile between 1990 and 2010 (i.e. lower peaks, higher background concentrations) contributes to the difference in modelled trends. POD6SPEC appears to be better reproduced by the models than AOT40.

Impacts of ozone global wheat yield: predictions for 2030 under current legislation

30. In collaboration with EMEP/ Meteorological Synthesizing Centre-West (MSC-West), the ICP Vegetation evaluated the impact of full implementation of current air quality legislation on wheat yield in 2010 and 2030. The 2010 and 2030 emissions from the European Union ECLIPSE project were used to calculate the phytotoxic ozone dose (POD3IAM) and wheat yield losses due to ozone, assuming no change in climate and wheat production between 2010 and 2030.

31. Annual wheat yield losses due to ozone were similar for 2010 and 2030 due to rising emissions of methane and stable emissions of nitrogen oxides between 2010 and 2030. The highest percentage yield loss was estimated for South and Eastern Asia (yield loss 9.2 per cent and 9.0 per cent, production loss 28.9 and 28.3 million tonnes in 2010 and 2030 respectively), followed by the region of Eastern Europe, Caucasus and Central Asia (yield loss 7.8 per cent and 7.2 per cent, production loss 8.2 and 7.5 million tonnes in 2010 and 2030, respectively). The percentage yield loss was similar in Europe and North America (approximately 6.6 per cent and 5.5 per cent in 2010 and 2030 respectively), but the production loss was about twice as high in Europe (12.8 and 10.8 million tonnes in 2010 and 2030 respectively).

VII. Emissions

A. Improving emission inventories

32. The findings of the technical review were communicated to the national designated experts through the country-specific status and assessment reports. An overview of the findings for the stage 1 and 2 reviews is summarized in the joint the Centre on Emission Inventories and Projections (CEIP)-European Environment Agency Inventory Review

[12] AOT40 is the sum of the differences between the hourly mean ozone concentration (in ppb) and a threshold value of 40 ppb during daylight hours, accumulated over a stated time period.

[13] POD_6SPEC (‘Phytotoxic Ozone Dose’) is the accumulated uptake (flux) of ozone for the crop species (‘SPEC’) wheat above a threshold of 6 nmol m^{-2} s^{-1} during a specified growth period.

2019,14 available on the CEIP website. In depth review of 6 countries (Albania, Georgia, Norway, Russian Federation, Serbia, Turkey) has been performed in period April –July. All countries but Georgia communicated with review teams. Country reports will be posted on CEIP website before the fifth joint session (September 2019).

33. It is important to mention a recurring problem whereby some countries having an inventory review do not respond at all, or in a very minimum way, to questions raised by the expert review team. Given the significant resources being used within EMEP (and in-kind from Parties) to perform the review process and that these countries are typically the ones who might benefit the most from the capacity-building designed review process, it is important to understand the reasons for the non-responses and consider how this could be fixed for future reviews (given also that these countries should arguably be reviewed more often in the future under the new procedures).

34. Finally, the experts of the Task Force on Emission inventories and Projections identified the need for a stronger mechanism to ensure that simple 'Tier 1' methods should not be used for key emission sources, consistent with the principles specified in the Guidelines for reporting emissions and projections data under the Convention on Long-range Transboundary Air Pollution (Reporting Guidelines - ECE/EB.AIR/125). A proposal was made that the EMEP/EEA air pollutant emission inventory guidebook[15] (EMEP/EEA Guidebook) should remove all Tier 1 methods, but the implementation of such a decision is still under discussion (recognising the Guidebook is also used by a number of Parties who may not have ratified a protocol, but who may still wish to make a first emission estimate using Tier1).

35. There is an important issue regarding the quality of the emission inventories that are likely to be used to support policy processes. Indeed, the Greenhouse gas - Air pollution Interactions and Synergies (GAINS) model, developed by the Center on Integrated Assessment Modelling (CIAM) can be used for review process of the amended Gothenburg Protocol and can assess to what extent the long-term targets will be met (in 2020–2030–2050), when technical annexes of the amended Gothenburg Protocol will be implemented completely. As official emission data are sometimes incomplete, the task Force on Integrated Assessment Modelling advises to use expert estimates in such cases to guarantee equal treatment of countries.

Gridded emissions used for modelling

36. In recent years, CEIP developed and improved a gridding system with a resolution of 0.1° x 0.1° longitude/latitude, which is using different spatial proxies for the spatial disaggregation of gap-filled data on Gridding Nomenclature for Reporting (GNFR14) sector level. In 2019, gridded data of main pollutants (nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOC), ammonia (NH_3), sulphur oxides (SO_x), CO) and PM ($PM_{2.5}$, PM_{10}, PMcoarse) for the complete time series from 1990 to 2017 were prepared for the first time in the new resolution. Gridded data for heavy metals (HMs) (cadmium - Cd, mercury - Hg and lead - Pb) and persistent organic pollutants (POPs) (Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, dioxins and furans (PCDD/F), hexachlorobenzene (HCB)) where prepared for the year 2017. For the first time gridded black carbon (BC) emissions were prepared (2017 data) in 0.1 x 0.1 longitude/latitude resolution.

37. Where sufficient reported data was not available or data had to be replaced, expert estimates (from, for example, the GAINS model, TNO-MACC-II emission inventory funded by the Copernicus Atmosphere Monitoring Service, common reporting format (CRF) data under the European Union Greenhouse Gas Monitoring Mechanism (EU 2013), data from CAMS-REG-AP-v2.2 (ECCAD 2019), the emission data base for Global Atmospheric Research (EDGAR), the Global Mercury Assessment 2013, the POPCYCLING-Baltic project or the Global atmospheric emission inventory of Polycyclic Aromatic Hydrocarbons

[14] Marion Pinteris and others, Inventory Review 2019: Review of emission data reported under the LRTAP Convention and NEC Directive — Joint report of CEIP and EEA, Technical Report CEIP 4/2019 (Vienna, Environment Agency Austria, 2019) (forthcoming).

[15] See http://www.eea.europa.eu/publications/emep-eea-guidebook-2016.

(PAHs)) were used for gap-filling. Emissions for the sea regions were calculated using the CAMS global ship dataset for the years 2000 to 2017 (Finish Meteorological Institute, FMI 2019), provided via ECCAD (CAMS_GLOB_SHIP). Such approach can be developed thanks to good cooperation established by CEIP with other European and international air pollutant inventory initiatives.

38. The MSC-W and the Meteorological Synthesizing Centre-East (MSC-E) contributed, since gridded data is mainly used as input data for chemistry-transport models, to the review and evaluation of gridded emission data. Around 30 countries reported EMEP emissions in the new grid (0.1 x 0.1 degree resolution). EMEP/MSC-W model calculations, using these new data, have been compared to EMEP and Airbase observations and to model runs using another widely used European emission data set developed by the Research community for the Copernicus programme (CAMS-REG-AP, based on European proxies, not national data). The results indicate that for most countries, the use of the nationally gridded emission data improves the spatial correlation of the model results (for NO_2 especially) compared to observations. It is encouraging that the quality of the submitted gridded emission data for many countries seems to be rather high, compared to 2017.

The condensable issue

39. Modelling of particulate matter (PM) and use of expert-emissions for primary PM (PPM) strongly suggests that PM emissions in Europe are currently underestimated, and condensable PM[16]from the residential combustion sector, in particular wood burning, are a key source for these missing emissions. At present, the treatment of condensables in reported EMEP emission inventories vary from one country to the other and from one emission source to another, but to a large extent the condensable component is missing in the emission estimates. In addition to causing underestimation of modelled PM, the lack of the condensable component can strongly influence air pollution concentration maps and the source receptor matrices used in integrated assessment modelling.

40. Last year EMEP Steering Body requested the Parties to document in their Informative Inventory Report (IRR) how they deal with the condensable part of PM emissions they report, sector by sector. CEIP updated the IRR template to facilitate this work. Seventeen Parties provided information on the inclusion of the condensable component in PM_{10} and $PM_{2.5}$ emission factors (Austria, Belgium, Croatia, Estonia, Germany, Finland, France, Latvia, Netherlands, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom)[17] for the first time in 2019.· This reporting is a first step towards a better understanding of the reported PM data. However, the reporting in 2019 showed that in many cases Parties do not have the information if the PM emissions of a specific source category include the condensable component. The status of inclusion or exclusion is best known for the emissions from road transport. It is expected that the reporting will improve over the coming years, with more parties reporting the information and with a higher quality of the reported information.

41. A set of model runs (for 5 test countries; Belgium, Italy, the Netherlands, Norway, Poland) based on expert emissions including or excluding the condensables component was performed by MSC-West in order to illustrate the possible quantitative effect of this. The effect of including condensables varies from country to country (depending on e.g. the amount of condensables in that country). Among the 5 test cases, the effect was largest for Poland, where reducing PPM is ~40 per cent more efficient for absolute $PM_{2.5}$ concentration when condensables are included (inclusion of condensables increase the Polish primary PM contribution to Polish $PM_{2.5}$ by ~40 per cent). For the other countries the effect was smaller, in some cases almost negligible. In summary, the inclusion of condensables will probably affect the source receptor matrices for different countries in very different ways.

[16] The condensable component of particulate matter is released as a gas but forms particles when it is diluted and cools down.

[17] Status as at 30 April 2019.

Black carbon emissions

42. CEIP continued to contribute to the 2018–2020 *European Union Action on Black Carbon in the Arctic* (EUA-BCA)[18]. The project, led by the Arctic Monitoring and Assessment Programme Secretariat, is the European Union initiative to support international policy action to reduce black carbon emissions. The technical report *Review of Reporting Systems for National Black Carbon Emissions Inventories* was finalized in Spring 2019, with CEIP significantly contributing by emissions data as well as a review of both the black carbon inventory methods recommended in the EEA/EMEP Guidebook and the current level of black carbon emissions reporting under the Convention.

43. Black carbon emission data are gathered on a voluntary basis from the Parties following the reporting process. Despite a large number of Parties voluntarily reporting black carbon emissions, the review revealed a number of shortcomings and made a number of recommendations e.g. calling for the EMEP/EEA Guidebook to be improved in terms of the extent to which higher Tier black carbon inventory methods are available and recommending that black carbon reporting be mandatory. A pre-print version of the report is already available online,[19] with the final version set to be published on the Action's website in summer 2019.

B. Applications for adjustments to emission inventories

44. All submitted adjustment applications, both new and previously approved have been assessed by the Expert Review Team (ERT). The Netherlands submitted new adjustment applications in 2019, and 7 parties (Belgium, Denmark, Hungary, Finland, France, Germany, Luxembourg, Spain and the United Kingdom) submitted Annex VII for application already approved. Recommendations to Steering body to EMEP are provided in a status report on adjustments.[20] Approved adjustments reported in Annex VII have been imported in the website tool[21], where all information can be easily viewed and compared.

VIII. Monitoring strategy

Revision of the monitoring strategy

45. The Chemical Coordinating Centre (CCC) together with the experts of the Task Force on Measurements and Modelling prepared the revision of the EMEP monitoring strategy as planned. The proposal for revision has been prepared taking into consideration recent developments in other relevant initiatives like the Arctic Monitoring and Assessment Programme, WMO Global Atmosphere Watch, European Union Directives, Minamata and Stockholm Conventions. The text has been finalised by the experts during the annual meeting of the Task Force on Measurements and Modelling.

46. Actually, no major change is proposed for the new monitoring strategy compared to the previous one. It will be still organized according to three levels, level 1 being mandatory for Parties and level 3 only voluntary (on the basis of international or national scientific programmes). For example, it is proposed to move elemental carbon and organic carbon in PM_{10} and hourly measurements of nitrogen dioxide from level 2 top level 1. Alignment with the Global Atmosphere Watch and with the European Union ACTRIS Research Infrastructure is also suggested. The final text will be considered for adoption during the fifth joint session of EMEP Steering Body/Working Group on Effects in September 2019.

47. It is reminded that the last EMEP field campaign was focused on better knowledge of carbonaceous compounds (and black carbon) in particulate matter and their sources with the

[18] https://eua-bca.amap.no/.
[19] https://eua-bca.amap.no/news/2019/eua-bca-technical-report-review-of-reporting-systems-for-national-black-carbon-emissions-inventories.
[20] See http://www.ceip.at/adjustments_gp/adj_country_data/.
[21] See http://webdab1.umweltbundesamt.at/adjustments_GP.

implementation of high time-resolution and on-line devices such as multi- wavelengths aethalometers. Chemical analysis of relevant tracers like levoglucosan completed the network. Winter period (December 2017-March 2018) was targeted to highlight the contribution of biomass burning in winter particulate episodes. Twenty-two countries participated to the field campaign and 57 sites were monitored. CCC gathered all data that will now be used by the modelling teams from MSC-West, and MSC-East and by national experts to assess current models performances in reproducing carbonaceous compounds concentrations in European. A new model intercomparison exercise will be launched under the aegis of the Task Force on Measurement and Modelling, as a follow-up of the Eurodelta initiatives.

IX. Linking the scales

48. According to the Task Force on Integrated Assessment Modelling analysis, comparison of national air quality plans showed that countries only looked at the domestic impacts for their plan but not at the transboundary benefits (while taking into account benefits from measures in other countries). Even in national methodologies for cost-benefit analysis of projects or policy measures, transboundary impacts are omitted in most countries. The Task Force on Integrated Assessment Modelling (TFIAM) advises to use all external costs in cost-benefit analysis and also report on (reduced) transboundary health and ecosystem damage.

49. At the city level a focus on exceedances of limit values in certain streets leads to other policy measures than when the focus is on reducing average exposure and maximizing health improvement. The second approach would be more cost-effective, but requires more regional or (inter)national cooperation. TFIAM advises to take both approaches into account and show trade-offs between efficiency and equity.

A. The twin sites project

50. To establish scientific evidences of the linkages between local and regional air pollution and characterize them, the Task Force on Measurements and Modelling set up in 2017 a new project, called the "twin site" project. This project aims at investigating several approaches based data collected at monitoring stations and modelling experiments.

51. The monitoring approach is coordinated by national experts from Spain and is based on use of triples of urban/suburban/backgrounds monitoring sites in France, Germany, the Netherlands, Spain and Switzerland.

52. Modelling approaches are based on several tools. The GAINS model methodology developed by the Centre on Integrated Assessment Modelling can be used for assessing local/non-local contributions to air pollution. Also, French experts investigated the ability of EMEP model and of the multi-scale chemistry-transport models to capture both observed urban/rural gradients in total PM_{10} and individual chemical species used in the "twin site" analysis.

53. A Twin Site methodology for assessing the local/non-local contribution of air pollution to urban air from observations has been assessed by Spanish experts. This approach relies on incremental decomposition (the so-called "Lenschow" approach) applied to the positive matrix factorization (PMF) decomposition of fine chemical characterisation of aerosols. It was applied to observations at paired or tripled sites in France, Germany, the Netherlands, Spain and Switzerland. Overall, the urban increment ranges between 18 to 35 per cent, highlighting the substantial contribution of long-range air pollution even in urban areas. Conclusions of the twin site project will be published in 2019.

54. Model assessment of heavy metal and POP pollution of the EMEP countries was carried out by MSC-East. Results of the operational modelling include information on Pb, Cd, Hg, PAHs, PCDD/Fs, PCBs, and HCB concentrations, deposition, and transboundary transport. In addition, complementary information products, such as ecosystem-specific

deposition, atmospheric loads to watersheds etc., were generated to contribute to the work under the Working Group on Effects.

55. The research activities were carried out in accordance with the priorities of the long-term strategy for the Convention. In particular, a new mechanism of Hg photo-reduction in the atmosphere was tested and evaluated. Besides, downscaling of heavy metal pollution from regional to national scale was initiated in the framework of a country-specific study for Germany. Evaluation of the key B(a)P processes, degradation and gas-particle partitioning, was continued in close cooperation with national experts from France and Spain. Analysis of model uncertainties related to HCB accumulation in media and re-emission to the atmosphere was commenced.

56. MSC-East also contributed to the work of TF TEI aimed at promoting the ratification of the Convention Protocols by the countries in Eastern Europe, the Caucasus and Central Asia countries. Particular attention was given to the co-operation with international organizations including AMAP, Stockholm Convention, Minamata Convention, HELCOM, etc.

B. Hemispheric transport of air pollution

57. The Task Force on Hemispheric Transport of Air Pollution finalized the publication of a special issue of the journal *Atmospheric Chemistry and Physics*,[22] comprising 48 articles drawing upon the results of recent global and regional modelling experiments for ozone and fine particles coordinated with the Air Quality Model Evaluation International Initiative and the Model Intercomparison Study-Asia. Authors of the articles came from countries who are Parties to the Convention, as well as from China, India, Japan and South Korea.

58. The recent findings of the Task Force on Hemispheric Transport of Air Pollution F HTAP confirm earlier analyses showing that the sensitivity of annual ozone levels in Europe to emissions changes that occur outside Europe is equal to or larger than the sensitivity to emissions changes that occur within Europe. However, the recent results suggest that the sensitivity varies depending on the ozone metric of interest, with the health-oriented sum of hourly concentrations over 35 ppb (SOMO35) showing less sensitivity to emissions outside Europe than the annual average. Furthermore, the sensitivities of ozone concentrations in regional models are driven by the model boundary conditions used to estimate transport of ozone into the regional domain in the free troposphere (i.e. above the mixed layer). Continued research is needed to improve the evaluation of global models for the purpose of providing regional model boundary conditions.

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[22] https://www.atmos-chem-phys.net/special_issue390.html.