CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION

WORKING GROUP ON EFFECTS

INTERNATIONAL COOPERATIVE PROGRAMME ON EFFECTS OF AIR POLLUTION ON NATURAL VEGETATION AND CROPS (ICP VEGETATION)

ICP VEGETATION

Final draft minutes of the 22nd Task Force Meeting

The twenty-second meeting of the Programme Task Force was held from 2 – 4 February, 2009 in Braunschweig, Germany and hosted by the Institute of Biodiversity, Johann Heinrich von Thünen-Institute (vTI).

1. The meeting was attended by 55 delegates from 20 Parties to the Convention: Austria, Belgium, Croatia, Czech Republic, Finland, France, Germany, Greece, Hungary, Italy, Lithuania, Netherlands, Norway, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom. Also present were the secretariat for the LRTAP Convention at the United Nations Economic Commission for Europe (UNECE), the chairman of the ICP Modelling and Mapping, the chairman of the ICP Forests Working Group on Ambient Air Quality, a representative from EMEP/MSC-East and two guests from South-Africa.

2. The Programme Task Force adopted the agenda of the meeting.

3. Mr Harmens (chairman of the ICP Vegetation, UK) welcomed all participants on behalf of the ICP Vegetation Programme Centre and thanked vTI for hosting the meeting. Mr Thoroe, President of vTI, welcomed the participants to Braunschweig. Mr Grugel welcomed the participants to Germany on behalf of the Federal Ministry of Food, Agriculture and Consumer Protection and emphasized the importance of the work conducted by the ICP Vegetation within the framework of the Working Group on Effects of the Long-range Transboundary Air Pollution Convention.

4. Mr Johansson (secretary for the WGE) gave an overview of the organisation of the Convention and its protocols. He highlighted relevant matters arising from meetings of other Convention bodies, including (see http://www.unece.org/env/lrtap/welcome.html):
   - 26th Session of the Executive Body for the Convention;
   - 41st and 42nd Session of the Working Group on Strategies and Review;
   - 32nd Session of the EMEP Steering Body;
   - 27th Session of the Working Group on Effects;
   - 34th Meeting of the Task Force on Integrated Assessment Modelling (TFIAM);
   - 1st Meeting of the Task Force on Reactive Nitrogen (TFRN).

He encouraged collaboration between ICP Vegetation and other Convention bodies, in particular TFIAM and TFRN (see paragraph 7 for details).

5. Mr Spranger (chairman of the ICP Modelling and Mapping, Germany) reported on the activities of the ICP Modelling and Mapping in 2008-2009 and the results of its 24th Task Force Meeting. He emphasized the importance of collaboration with other ICPs, in particular on the exchange of data and methods and the common workplan items of the WGE (see paragraph 7 for details). Regarding nitrogen he highlighted the focus on effects on biodiversity in terrestrial ecosystems, ensemble assessment of impacts to improve robustness and noted that the 2007/8 critical loads data should be used for policy applications, including the Gothenburg Protocol revision. Mr Spranger encouraged the ICP Vegetation to contribute to the ongoing European Nitrogen Assessment (see http://www.nine-esf.org for details).

6. Mr Schaub (chairman of the ICP Forests Working Group on Ambient Air Quality, Switzerland) reported on ozone concentrations, exposures and visible injury on ICP Forests level II plots. He described the current status of ozone risk assessment and noted that field-based evidence of ozone impacts on forests is limited as forest monitoring usually concentrates on non-specific response indicators and visible ozone-like injuries were considered only recently. Nevertheless, a significant linear trend between AOT40 and ozone symptom development was observed based on a limited data set. Elevated ambient ozone exposure caused visible injury on natural vegetation every year. Mr Schaub encouraged continued collaboration between ICP Vegetation and ICP Forests on further development of ozone risk assessment for forest trees, in particular regarding the development of flux-effect relationships for mature trees.

7. Mr Harmens (UK) gave an overview of ICP Vegetation activities and achievements in 2008. First of all, Mr Harmens highlighted that the Executive Body of the Convention at its 26th Session (15 – 18 December 2008; see ECE/EB.AIR/96):
   - Decided that '…. ozone effects on vegetation be incorporated in integrated assessment modelling, especially in work for the revision of the Gothenburg Protocol, and recommended that the flux-based methods be used for this';
   - Took note '…. that the implementation of existing legislation would not attain the ambition levels set out in article 2 of the Gothenburg Protocol ….; in particular, it would not provide a significant reduction in effects of ozone on health and vegetation, and the policies aiming only at health effects would not protect vegetation in large areas of Europe'.

   He informed the Task Force on progress made with the ICP Vegetation workplan items for 2009 (listed in annex I). The items will be presented at the 28th session of the WGE, 23 – 25 September 2009, Geneva (for further details see http://www.unece.org/env/wge/documents.htm, where meeting documents can be downloaded in due course).

   Mr Harmens reported on progress made with the specific ICP Vegetation workplan items for 2009, which will be reported in more detail in ECE/EB.AIR/WG.1/2009/3 & 9:

   - *Report on the risk of damage to (semi-)natural vegetation communities in Europe*. The Ellenberg modelling method (ECE/EB.AIR/WG.1/2007/9) was extended to predict ozone sensitivity of European grasslands under the EUNIS (European Nature

Information System) classification, including coastal grasslands. Grassland communities predicted to be most sensitive to ozone are coastal communities, followed by Mediterranean tall humid grasslands and Calcareous alpine and sub-alpine grasslands. A first attempt was made to map grasslands at risk from ozone.

- *Report on flux-based assessment of risk of damage to managed pastures in Europe*. The DO_3SE (Deposition of Ozone and Stomatal Exchange) grassland flux model developed at the Stockholm Environment Institute in York, UK, was further developed into a multi-layer model with generic parameterisations based on the grass species *Lolium perenne* and the legume species *Trifolium repens*. This allows ozone fluxes to be estimated to different components of a vegetation canopy. The first maps of ozone fluxes to grasses and legumes in managed pastures were presented. So far it's difficult to derive robust flux-response relationships for managed pastures due to the lack of appropriate datasets.
- *Report on ozone exposure and impacts on vegetation in the Nordic Countries and the Baltic States*. A workshop on this theme was held on 17 – 18 June 2008 in Gothenburg, Sweden, organised by Swedish Environmental Research Institute (IVL) and the University of Gothenburg. The meeting was attended by 16 delegates from Estonia, Finland, Latvia, Russian Federation and Sweden (with additional input from Norway). The workshop highlighted that European ozone risk assessments for negative impacts on vegetation should be flux-based (see also paragraph 10).
- *Report on the temporal trends in heavy metal concentrations in mosses between 1990 and 2005*. Europe-wide the metal concentration in mosses has declined since 1990 for arsenic, cadmium, copper, iron, lead, nickel, vanadium and zinc, but has hardly changed for chromium and mercury. The report on 'Spatial and temporal trends in heavy metal accumulation in mosses in Europe (1990-2005)' is available from the ICP Vegetation web site (http://icpvegetation.ceh.ac.uk).
- *Report on the spatial variation in heavy metal and nitrogen concentrations in mosses.* Statistical analysis of factors influencing the spatial variation of heavy metal and nitrogen concentrations in mosses in 2005, conducted by the University of Vechta, Germany, showed considerable correlations between cadmium and lead concentrations in mosses and EMEP emission and urban land use data. Mercury showed weak correlations with tested predictors. High correlations were found between nitrogen concentrations in mosses and agricultural and urban land use data and agricultural and population density data.

Workplan items common to bodies under the WGE (all ICPs and the Task Force on Health):

- *Status report on airborne nitrogen impacts on the environment (in collaboration with the Task Force on Reactive Nitrogen (TFRN) and the Task Force on Integrated Assessment Modelling(TFIAM)).* Mr Harmens referred to the ICP Vegetation report on 'Impacts of nitrogen on vegetation' (see http://icpvegetation.ceh.ac.uk) and collaboration with the TFRN, which will have its second meeting on 28 – 29 April 2009 in Garmisch Partenkirchen, Germany (see http://www.clrtap-tfrn.org).
- *Compilation report on selected key monitored and modelled parameters, tentatively based on the guidelines on reporting of monitoring and modelling of air pollution effects.* The WGE guidelines on reporting (ECE/EB.AIR/WG.1/2008/16) were adopted by the Executive Body of the Convention at its 26th Session with the Decision 2008/1. Annex 1 of the guidelines describes selected key parameters to be monitored and modelled, including those for vegetation.

- *Report on update of the strategy of the effects-oriented activities.* The long-term strategy of the WGE will be reviewed in 2009.
- *Explore merits of different options for target setting in 2020 and non-binding aspirational targets for 2050 (in collaboration with TFIAM and the Centre of Integrated Assessment Modelling (CIAM)).* ICP Vegetation will contribute to workshops on this item organised by TFIAM. The first workshop on aspirational targets for 2050 will be on 5th – 6th March 2009 in Utrecht, the Netherlands. The second workshop on targets for 2020 will be in October/November 2009. Mr Harmens informed the Task Force of the recently established Network for Integrated Assessment Modelling (NIAM; see http://niam.scarp.se) and urged relevant Parties to explore collaboration with NIAM.
- *Further quantification of policy-relevant effects indicators such as biodiversity change, and to link them to the integrated modelling work.* Although little information is available on the impacts of ozone on biodiversity, considerable information exists on the impacts of ozone on crop yield and crops quality that could be used in a policy-relevant manner.

Mr Harmens concluded by summarising the outputs from the ICP Vegetation in 2008, including its contribution to WGE documents and thanking the Parties for their contribution to the ICP Vegetation.

8. Mr Weigel (Director of the Institute of Biodiversity, vTI, Germany) gave an overview of the research activities at the Institute of Biodiversity, one of the fifteen institutes of vTI. Fields of research include soil biology, agroecology, agri-environmental measures and monitoring processes/indicators. Of primary importance to the ICP Vegetation is the research on impacts of ozone and climate change on crops, conducted by a research team led by Mr Bender.

9. Mr Franzaring (Germany) informed the Task Force on the establishment of a European standard for biomonitoring using the grass culture method. Pre-grown ryegrass is exposed for four weeks in self-watering containers at a standard height of 1.5 m around emission sources or in regional biomonitoring networks. Pollutants analysed in the grass culture include heavy metals, sulphur, fluoride and polycyclic aromatic hydrocarbons (PAH).

10. Mr Karlsson (Sweden) presented the outcome of a workshop on 'Ozone exposure and impacts on vegetation in the Nordic countries and Baltic States', organised by the Swedish Environmental Research Institute (IVL) and the University of Gothenburg, 17 - 18 June 2008 in Gothenburg, Sweden. The overall aim of the workshop was to support policymakers with the scientific background in support of the ozone flux concept for European ozone precursor emission abatement. The magnitude of the impact of certain concentration-based ozone exposure can be higher in northern compared to southern Europe due to a higher ozone uptake by vegetation in the more humid climate of northern Europe. Results of the workshop will be presented in a special issue of AMBIO at the end of 2009.

11. Mr Büker (UK) gave an overview on impact of air pollution on crops in South Asia and southern Africa, which was part of the Regional Air Pollution in Developing Countries (RAPIDC) programme. The established Air Pollution Crop Effect Network (APCEN) expressed its wish to continue its work on modifying ozone risk assessment methods

developed under the ICP Vegetation for Asian and southern-African conditions and continue its collaboration with ICP Vegetation. On behalf of Mr Saxena (India), Mr Harmens (UK) gave a brief overview of heavy metal biomonitoring activities with mosses in India and the Task Force took note of the wish of Mr Saxena to contribute data from India to the moss survey. During the ensuing discussion Mr Harmens (UK) informed the Task Force of the unsuccessful attempts that were made to find funding for participants of Malé Declaration countries to attend the 22nd Task Force Meeting. The Task Force encouraged the Secretariat of the Malé Declaration to support participation of experts from its countries in future Task Force Meetings and encouraged further activities on outreach to areas outside the ECE region.

12. The meeting split into two parallel sessions considering the ozone and heavy metals/nitrogen sub-programmes. The topics of oral presentations in the parallel sessions are given below, for further details on the content of oral presentations and posters we refer to the book of abstracts and powerpoint files, both available on the ICP Vegetation web site (http://icpvegetation.ceh.ac.uk).

13. In the first ozone session, Ms Bassin (Switzerland) described the effects of combined ozone and nitrogen deposition on a sub-alpine pasture, Mr Håkan Pleijel (Sweden) reported on a meta-analysis on growth dilution/concentration effects of ozone and carbon dioxide on the content of starch, nitrogen, zinc, manganese and cadmium in wheat grain, Ms Wyness (UK) discussed ozone and nitrogen controls on carbon allocation within two (semi-)natural plant species and Mr Grünhage (Germany) evaluated the ozone-flux approach for use in ozone risk assessment for winter wheat at the local scale.

14. Presentations in the second ozone session focussed on ozone flux and model development in grasslands. Mr Fuhrer (Switzerland) reported on ozone flux in alpine grassland and Mr Büker (UK) described the development and provisional application of a multi-layer grassland flux model. Ms Hayes (UK) had developed flux-effect relationships for above- and below-ground impacts of ozone on two semi-natural grassland species and Mr González Fernández (Spain) reported on progress with modelling stomatal ozone flux of dehesa annual grasslands in central Spain. The session finished with a general discussion on local parameterisations for flux models and possible subjects for the proposed ozone workshop in Ispra (see paragraph 15).

15. In the third ozone session, Ms Mills (UK) reported on the outcome of the first meeting of the scientific committee of the next ozone workshop to be held on 10-12 November in Ispra, Italy. The meeting will be hosted by Mr Cieslik at the Joint Research Centre (European Commission) and is titled: 'Flux-based assessment of ozone effects for air pollution policy. *A focus on crops and grasslands*.' The aims of the meeting are to i) Improve application of flux-based methods described in the Modelling and Mapping Manual and ii) Further inform the LRTAP Convention on current impacts of ozone and guidelines for monitoring impacts in the future. Three working groups were suggested: 1) Integrated assessment modelling – what do we need to contribute?; 2) Evalution of flux method and scales of application of flux-based methods; 3) Evidence of impacts, guidelines for monitoring. The Task Force agreed to this proposal and added that members of the forest flux modelling subgroup would also be invited.

16. Ms Mills continued to present the outcome of the bean biomonitoring experiment in 2008 and led the discussion on the future work programme of the ozone sub-group. The group

decided not to conduct the planned comprehensive ozone biomonitoring study in 2010 (including NATURA2000 sites), but to repeat the bean biomonitoring experiment in 2009 and following years with greater participation from Parties. The bean biomonitoring protocol was revised and will be circulated by the Programme Coordination Centre at the start of the experimental season.

17. Review studies agreed at the 21st Task Force Meeting are well on their way or have been initiated. Further details can be found in the workplan of the ICP Vegetation (Annex I).

18. In the final ozone session, the following topics were presented: How does resource availability affect plant response to ozone? (Ms Power, UK), impact of tropospheric ozone on food and feed quality of Brassica species (Ms Vandermeiren, Belgium) and interactions between sulphur dioxide fumigation and drought stress on growth, photosynthesis and symbiotic nitrogen fixation in soybean (Ms Heyneke, South Africa).

19. In the first heavy metal/nitrogen session, Mr Harmens (UK) described the spatial and temporal trends in heavy metal accumulation in mosses in Europe between 1990 and 2005 (see also paragraph 9). Mr Schröder (Germany) reported on a Europe-wide analysis of factors influencing the spatial variation of cadmium, lead and mercury concentrations in mosses using geostatistics (see paragraph 9 for a summary of the results). Mr Leblond (France) compared the relationship between atmospheric deposition and element concentration in mosses for nitrogen and other elements in France.

20. Mr Ilyin (EMEP-MSC/East, Russian Federation) provided examples of the relationship between modelled EMEP heavy metal deposition and heavy metal concentrations in mosses for cadmium, lead and mercury and evaluated spatial and temporal patterns. He emphasized the higher spatial resolution of the moss data (ca. 6000 sites) and the extension of the moss survey into southern and eastern Europe in comparison to the EMEP measurement stations (ca. 100 for lead and cadmium and ca. 20 for mercury). From the preliminary analyses he concluded that: i) Comparison of measurements in mosses and modelled deposition fluxes is extremely useful for the validation of the EMEP transport model and the complex analysis of temporal trends and spatial distribution of pollution levels; ii) For Europe as a whole the spatial patterns of modelled deposition fluxes and concentration in mosses are similar; iii) Significant spatial correlations between modelled deposition and concentrations in mosses were found for Scandinavia and some central European countries; iv) Long-term modelled deposition trends of cadmium, mercury and lead agree reasonably well with trends in concentrations in mosses. Mr Ilyin encouraged further collaboration between EMEP-MSC/East and ICP-Vegetation regarding the joint analysis of heavy metal pollution levels across Europe.

21. Presentations in the second heavy metal/nitrogen session focussed on nitrogen. First of all, Mr Harmens (UK) described the spatial trends in nitrogen concentrations in mosses across Europe in 2005/2006 and compared the concentration in mosses with modelled EMEP nitrogen deposition data for 2004. Mr Zechmeister (Austria) reported on the total nitrogen concentration and $\delta^{15}N$ signatures in mosses as an indicative value for nitrogen deposition patterns and source allocation on a nation-wide scale. Mr Mohr (Germany) followed with a presentation on biomonitoring of nitrogen pollution using bryophytes, discussing the possibilities and limitations. Mr Werner (Germany) reported on the nitrogen concentrations and $\delta^{15}N$-ratios in epiphytic lichen *Xanthoria parietina* in correlation with nitrogen deposition rates and $\delta^{15}N$-ratios of colonised tree bark. In the

ensuing discussion it was concluded that mosses can potentially be used as biomonitors of atmospheric nitrogen deposition. Some confounding factors affecting the relationship between nitrogen concentrations in mosses and atmospheric nitrogen deposition were identified and require further investigation. The sub-group decided that the nitrogen concentration in mosses should be determined again in the 2010 moss survey and encouraged more Parties to do so to enhance the coverage across Europe. The challenge for the future will be to establish below which nitrogen concentration in mosses there will be no adverse effects of nitrogen on ecosystems, in order words, to define nitrogen critical loads based on nitrogen concentrations in mosses.

22. In the third heavy metal/nitrogen session, Mr Steinnes (Norway) presented the strong and weak points of the moss biomonitoring technique for metal deposition based on 30 years experience in Norway and Mr Harmens (UK) reported on uncertainties in the European moss data. The group reviewed the moss monitoring manual and discussed preparations for the 2010 moss survey and the future of the heavy metals and nitrogen work programme. Mr Harmens will amend the monitoring manual based on comments made and circulate the draft version of the monitoring manual for 2010 before finalising it in the summer of 2009. Although many participants in the moss survey have expressed the intention to participate again in the 2010, hardly any have secured funding at this stage. Therefore, the group urged Parties to the LRTAP Convention to support participation in the 2010 moss survey.

23. In the final heavy metal/nitrogen session, the following topics were presented: Biomonitoring of long-lived radionuclides in Belarus 20 years after Chernobyl (Ms Frontasyeva, Russian Federation), biomonitoring of trace elements in Croatia (Mr Spiric, Croatia), response of mosses to atmospheric deposition of eight metals in Bulgaria and Switzerland for the period 1990-2005 (Ms Thöni, Switzerland) and landscape factors significantly controlling element distribution in mosses in the Czech Republic (Mr Suchara, Czech Republic).

24. In the final plenary session, Ms Mills (UK) gave an overview of presentations, conclusions and recommendations from the ozone sub-group, including plans for the LRTAP Convention ozone workshop in November 2009 (see paragraph 15), followed by a summary from Mr De Temmerman (Belgium) on the presentations and the outcome of discussions in the heavy metal/nitrogen sub-group. The Task Force took note of the conclusions and recommendations of both sub-groups (as described above). The Task Force discussed and adopted the medium-term (2010 – 2011) workplan of the ICP Vegetation as described in Annex I.

25. The Task Force discussed collaboration with other organisations/bodies:
    i) *Task Force on Integrated Assessment Modelling (TFIAM) and Centre for Integrate Assessment Modelling (CIAM)*. Ms Mills (Programme Coordination Centre, UK) will attend the TFIAM workshop on non-binding aspirational targets for air pollution for the year 2050, 5th - 6th March 2009, Utrecht, The Netherlands, and will give a presentation on 'Aspirational targets for the effects of ozone on vegetation.' (see paragraph 7).
    ii) *Task Force on Reactive Nitrogen*. The chair of the ICP Vegetation will attend the second meeting of this Task Force, 28 – 29 April 2009, Garmisch-Partenkirchen, Germany to inform the Task Force on ongoing work on nitrogen within the ICP Vegetation.

iii) *Malé Declaration*. The Task Force encouraged further collaboration with Malé Declaration countries (see paragraph 11). In addition, the Task Force encouraged outreach activities with colleagues in other countries (e.g. Cuba, South Africa, South America) who wish to collaborate with the ICP Vegetation.

iv) *European Commission*. The Task Force encouraged stronger links with the European Commission. A first step could be to invite delegates from the European Commission to the ozone workshop in November 2009 in Ispra. It is important that the ozone flux-based approach (rather than concentration-based methods) will form the basis of future European legislation on emission ceilings of air pollutants.

26. *Next ICP Vegetation Task Force Meeting*. No firm offer was received regarding the organisation of the 23rd Task Force Meeting, however, opportunities have been discussed with delegates from Belgium and Spain and will be further explored.

27. Mr Harmens (UK) closed the meeting by thanking Mr Jürgen Bender, Mr Hans Weigel and their colleagues at the Institute of Biodiversity, vTI, Braunschweig (Germany) for hosting the meeting. He thanked Ms Emberson (UK) and other members of the forest sub-group for their contributions to the local parameterisations of tree species and acknowledged the UK Department for Environment, Food and Rural Affairs (Defra), the United Nations Economic Commission for Europe (UNECE) and the Centre for Ecology and Hydrology for their continuous financial support of the ICP Vegetation Programme Coordination Centre. Mr Harmens also thanked the Secretariat and the Bureau of the WGE for their continuous support of the ICP Vegetation and other bodies of the LRTAP Convention, EMEP in particular, for their continuous collaboration with the ICP Vegetation. Last but not least he thanked his colleagues at the Programme Coordination Centre and the participants of the ICP Vegetation for their continuing support of the programme.

Annex I. ICP Vegetation work-plan for 2009 (*updated on 4th February 2009*)

2009:

Specific to ICP Vegetation:

- Report on the risk of damage to (semi-)natural vegetation communities in Europe [O];
- Report on flux-based assessment of risk of damage to managed pastures in Europe [O];
- Report on ozone exposure and impacts on vegetation in the Nordic Countries and the Baltic States [O];
- A glossy brochure and associated web page for the general public and other interested parties on field-based evidence for impacts of ozone on vegetation [O];*
- Report on the temporal trends in heavy metal concentrations in mosses between 1990 and 2005 [HM];
- Report on the spatial variation in heavy metal and nitrogen concentrations in mosses [HM, N].

Common to all ICPs/Task Force on Health:

- Status report on airborne nitrogen impacts on the environment (in collaboration with the Task Force on Reactive Nitrogen and the Task Force on Integrated Assessment Modelling);
- Compilation report on selected key monitored and modelled parameters, tentatively based on the guidelines on reporting of monitoring and modelling of air pollution effects;
- Report on the update of the strategy of the effects-oriented activities;
- Explore merits of the different options for target setting in 2020 and non-binding aspirational targets for the year 2050, in collaboration with the Task Force on Integrated Assessment Modelling and the Centre for Integrated Assessment Modelling;
- Further quantification of policy-relevant effects indicators such as biodiversity change, and to link them to the integrated modelling work.

2010:

- Report on ozone biomonitoring experiment with bean in 2009 [O];
- Report on ozone impacts in Mediterranean areas [O];
- Review of ozone flux modelling methods and their application to different climatic regions [O];
- Report of workshop on 'Flux-based assessment of ozone effects for air pollution policy. *A focus on crops and grasslands*' [O] ;
- Progress report on European heavy metals and nitrogen in mosses survey 2010 [HM, N];
- Report on the relationship between heavy metal concentration in mosses and EMEP modelled deposition [HM].

2011:

- Report on the 2010 biomonitoring exercise for ozone [O];
- Report on ozone impacts on food security [O];
- Report on ozone, carbon sequestration, and linkages between ozone and climate change (tentative) [O];
- Review of links between risk assessment maps for ozone and health (possibly) [O];
- Progress report on European heavy metals and nitrogen in mosses survey 2010 [HM, N];
- Review of the relationship between heavy metal and nitrogen concentrations in mosses and impacts on ecosystems [HM, N].

* Item not included in the official Convention's work-plan. [N]: Nutrient nitrogen, [O]: Ozone, [HM]: Heavy metals.