United Nations
ECE/EB.AIR/124

Economic and Social Council

Distr.: General
13 March 2014

Original: English

Economic Commission for Europe

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

Guidance document on health and environmental improvements using new knowledge, methods and data

Summary

At its thirty-second session (Geneva, 9–13 December 2013), the Executive Body for the Convention on Long-range Transboundary Air Pollution adopted a guidance document on health and environmental improvements using new knowledge, methods and data to the 1999 Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (Gothenburg Protocol) (ECE/EB.AIR/122/Add.1, decision 2013/23), and decided that it would be the guidance document referred to in article 5, paragraph 1 (e), and article 7, paragraph (3) (c), of the Gothenburg Protocol, as amended (ECE/EB.AIR/111/Add.1; see also ECE/EB.AIR/114 for the consolidated text).

This guidance document has been prepared by the Working Group on Effects, in cooperation with the Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe. The document focuses on the adverse effects of air pollutant emissions in the base year 2005 and for the projected baseline emissions in 2020.

GE.14-21366
1421366

Contents

I. Introduction

1. This Guidance document focuses on the effects of emissions in the base year 2005 and for the projected baseline emissions in 2020 under the amended Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (Gothenburg Protocol) (United Nations Economic Commission for Europe (ECE), 2012a and 2012b) to the Convention on Long-range Transboundary Air Pollution (Air Convention), following the revised Gothenburg Protocol and Current Legislation scenario (GP-CLE) air pollutant emission reduction scenario generated by the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP) Centre for Integrated Assessment Modelling (CIAM) and the Task Force on Integrated Assessment Modelling. The document provides information on selected indicators for health and environment for countries within the geographical scope of EMEP. These indicators are chosen on the basis of ECE (2008), and assessed under the Convention using the latest science of EMEP and the Working Group on Effects.

2. Section II provides a summary of each of these indicators, while section III describes ecosystem recovery mentioned in article 2 (a) and (b) of the 2012 amended Gothenburg Protocol (ECE, 2012c).

3. This Guidance document has been compiled by the Coordination Centre for Effects (CCE), Programme Centre of the International Cooperative Programme (ICP) on Modelling and Mapping Critical Levels and Loads and Air Pollution Effects, Risks and Trends, located at the National Institute for Public Health and the Environment in Bilthoven, the Netherlands. It includes inputs from the Programme Centres of the ICP on Effects of Air Pollution on Materials, including Historic and Cultural Monuments (ICP Materials), located at the Main Research Centre at the Corrosion and Metals Research Institute in Stockholm; the ICP on Effects of Air Pollution on Natural Vegetation and Crops (ICP Vegetation), located at the Centre for Ecology and Hydrology in Bangor, United Kingdom of Great Britain and Northern Ireland; CIAM, located at the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria; the EMEP Meteorological Synthesizing Centre-West (MSC-W), located at the Norwegian Meteorological Institute in Oslo; the Joint Task Force on Health Aspects of Air Pollution, located at the European Centre for Environment and Health in Bonn, Germany; and Econometrics Research and Consulting, located in the United Kingdom. It is an update of informal document No. 4 presented to the fiftieth session of the Working Group on Strategies and Review (Geneva, 10–14 September 2012).[1]

4. This document was reviewed at the Joint Session of the EMEP Steering Body and the Working Group on Effects (Geneva, 11 September 2013) and approved at the thirty-second session of the Working Group on Effects (Geneva, 12–13 September 2013) (ECE/EB.AIR/WG.1/2013/2, forthcoming).

II. Health and environmental improvements

5. Values for indicators on health and the environment are shown for 2005 in table 1, and for 2020 in table 2, while the relative improvement[2] of indicator values between the years is shown in table 3.

[1] Available from http://www.unece.org/index.php?id=29873.
[2] Health and environmental improvements presented in table 3 are computed as 100%*|Indicator2005 – Indicator2020)|/Indicator2005.

6. The health indicators are based on national population data from 2010 with no account taken of future population changes, to eliminate the possible effect of the latter on the change in risk from air pollution exposure. All indicators have been calculated using available data and methodologies according to the current state of science (September 2013).

7. Effects-based indicators of the Working Group on Effects have been analysed using the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model (Amann and others, 2011), including MSC-W knowledge and data, when these indicators are embedded or, otherwise, assessed as part of the GAINS system. In the latter case, CIAM (scenario) assumptions and MSC-W results are post-processed in effects-based models that are run under the Working Group on Effects.

8. The different indicators are expressed as set out below.

Health related to particulate matter and ground-level ozone exposure

9. Mortality related to particulate matter (PM) exposure is expressed as the average loss of life expectancy due to long-term exposure to anthropogenic fine PM ($PM_{2.5}$) for the whole population normalized to the national population in 2010.

10. Mortality related to short-term exposure to ground-level ozone is expressed as the number of premature deaths normalized by national population in 2010.

11. The analysis of morbidity effects[3] quantifies cardiovascular and respiratory hospital admissions for $PM_{2.5}$ and ozone. This is a subset of the morbidity effects associated with air pollution, because air pollution-related morbidity effects, such as chronic bronchitis and days of restricted activity, are not included. The morbidity indicator is normalized by national population. The annual average for $PM_{2.5}$ and the sum of ozone means over 35 parts per billion (ppb) (SOMO35) for ozone are based on recent CIAM and MSC-W modelling data (see also Amann and others, 2013). Incidence data for hospital admissions are taken from WHO (2013c). Functions for respiratory and cardiovascular hospital admissions for $PM_{2.5}$ for all ages, and for ozone in age classes over 65 years, can be found in WHO (2013b) and Katsouyanni (2009), respectively.

12. GAINS assessments of health indicators are included in Amann and others (2013).

Acidification

13. Acidification (caused by emissions of sulphur and nitrogen compounds) is expressed as the percentage of ecosystem area where the critical load for acidification is exceeded and as the average accumulated exceedance (AAE) (Posch and others, 2001). The former illustrates the geographic extent of the occurrence of exceedances, and the latter, the exceedance magnitudes within these areas. Calculations have been performed using the most recent critical loads database (Posch, Slootweg and Hettelingh, 2012).

Eutrophication

14. Eutrophication (caused by nitrogen compounds) is expressed as the percentage of ecosystem area where the critical load for nutrient nitrogen is exceeded and as AAE (Posch, Hettelingh and De Smet, 2001). The former illustrates the geographic extent of the occurrence of exceedances and the latter the exceedance magnitudes within these areas.

[3] Morbidity caused by nitrogen dioxide is not included.

Biodiversity, illustrated as species richness in grasslands

15. The Executive Body to the Air Convention's invitation in 2007 to the Working Group on Effects "to consider further quantification of policy-relevant effect indicators such as biodiversity change, and to link them to integrated modelling work" (ECE, 2007) has stepped up work by ICPs to review biodiversity indicators (Hettelingh, Posch and Slootweg, 2009; Working Group on Effects, 2013) and possibly apply them in the scenario analysis of emission reductions.

16. This Guidance document describes the tentative application of a nitrogen dose-response relationship (Stevens and others, 2010 on specific European grasslands that are distinguished in the European Nature Information System (EUNIS)[4], i.e. classes E1 (including E1.7 and E1.9), E2 and E3. This tentative use of the dose-response relationship can illustrate species richness — for any nitrogen emission reduction scenario — as a percentage compared with a hypothesized 100 per cent species richness at zero nitrogen deposition. The analysis (Working Group on Effects, 2013; Hettelingh and others, forthcoming) was restricted to grasslands at locations with precipitation between 490 and 1,971 millimetres per year, at an altitude below 800 metres and with a soil pH if less than 5.5. These restrictions were applied to ensure that only grasslands with precipitation and soil pH within the range of conditions found in the original data set were considered. The limitation of available precipitation data led to the analysis being restricted to EUNIS areas located west of 32ºE. It should be noted that the assessment results are uncertainty prone.

Vegetation related to ground-level ozone exposure

17. The impact on vegetation related to ground-level ozone is expressed as the percentage reduction in wheat yield, calculated using the flux-based method (Mills and Harmens, 2011; Mills and others, 2011; Mills and others, 2013) presented as the mean per EMEP grid square for the squares where wheat is grown and assuming irrigation is used when needed. Wheat is the most extensively grown crop in Europe and is one of the most sensitive European crops to ozone along with soybeans, peas and beans. Maize, barley, oilseed rape, potato and tomato are moderately sensitive to ozone. The proportion of wheat-growing grid squares predicted to have 5 per cent or more yield loss[5] was 88 per cent in 2005 and 83 per cent in 2020.

Materials related to air pollution exposure

18. For corrosion of materials the relation is expressed as the percentage area where the corrosion rate of carbon steel, zinc or limestone exceeds the background corrosion rate by a factor of two, calculated by dose-response functions for the multi-pollutant situation (Kucera and others, 2007). For soiling, the relation is expressed as the percentage area where the loss in reflectance of non-transparent materials calculated by dose-response functions (Watt and others, 2009) compared to unsoiled surfaces exceeds 35 per cent in 20 years. The 35-per-cent level indicates the need to clean the material. Scenario-independent data used in the calculations (temperature, relative humidity, precipitation) are from New and others (2002).

[4] See http://eunis.eea.europa.eu/about.jsp.

[5] The per cent yield losses are calculated using the generic crop flux model (CLRTAP, 2013) and a critical level has not been officially made for this model. However, it is likely to be set at 5 per cent like the other wheat-based critical levels that are given in CLRTAP (2013).

III. Recovery of ecosystems

Acidification

19. Recovery from the adverse effects of acidification can be achieved when the critical load is not exceeded. When recovery is required by a specified year (target year) a deposition value (target load) is required to enable the chemical criterion to attain a non-critical value in the target year. The chemical criterion used for critical loads calculations is linked to the biological effects of acidifying pollutants. The improvement of exceedance of critical loads for acidification (table 3) can include recovery.

Eutrophication

20. Recovery from the adverse effects of eutrophication may be achieved when the critical load is not exceeded. When recovery is required by a target year, a target load is required to enable the chemical criterion to attain a non-critical value in the target year. The chemical criterion used for critical load calculations is linked to biological effects of eutrophying pollutants. The improvement of exceedance of critical loads for eutrophication (table 3) can include recovery.

Table 1
Health and environmental indicator values for effects of emissions in 2005[a]

Party	*Mortality PM (average months lost per person)*	*Mortality ozone (cases.yr^{-1} per million people)*	*Morbidity PM and ozone (cases.yr^{-1} per million people)*	*Acidification (% area at risk)*	*AAE Acidification (mol H^{+}.ha^{-1}.yr^{-1})*	*Eutrophication (% area at risk)*	*AAE Eutrophication (mol N.ha^{-1}.yr^{-1})*	*Bio-diversity, as species richness in grasslands (%)*	*Wheat yield reduction ozone (%)*	*Materials corrosion (% area of country at significant risk)*	*Materials soiling (% area of country at significant risk)*
Albania	7	44	661	0	1	92	289	80	—	91	22
Austria	7	50	1 108	1	1	81	316	67	9	44	10
Belarus	7	49	478	15	38	100	460	82	—	6	0
Belgium	9	25	478	13	62	4	7	65	13	100	100
Bosnia and Herzegovina	6	60	676	12	61	72	233	82	—	35	3
Bulgaria	11	101	1 039	0	0	77	165	84	11	88	65
Croatia	8	77	618	5	32	96	502	78	—	73	35
Cyprus	6	49	211	0	0	100	281		—	0	49
Czech Republic	8	47	781	85	546	94	516	75	14	96	49
Denmark	6	27	371	36	112	100	718	75	11	73	86
Estonia	5	27	384	0	0	37	38	88	12	2	0
Finland	4	18	393	0	0	11	7	92	8	0	0
France	8	36	556	10	39	89	437	75	12	37	41
Germany	8	39	881	28	89	57	373	67	13	97	67
Greece	13	63	966	3	19	100	377	85	11	46	45
Hungary	11	78	1 122	22	90	100	667	75	15	100	99
Ireland	3	13	175	3	3	24	39	83	4	4	5
Italy	11	85	984	1	4	74	367	78	15	15	41
Latvia	6	39	547	14	23	93	201	86	13	13	0
Liechtenstein	—	—	0	24	8	100	455	77	—	—	—
Lithuania	6	41	773	34	170	98	390	82	13	12	0
Luxembourg	9	32	712	14	102	100	727	74	14	100	100
Malta	9	60	706	—	—	—	—	—	15	100	100
Netherlands	8	19	376	77	1 192	90	957	58	9	100	100
Norway	2	20	279	8	13	5	5	90	4	2	0

Party	*Mortality PM (average months lost per person)*	*Mortality ozone (cases.yr^{-1} per million people)*	*Morbidity PM and ozone (cases.yr^{-1} per million people)*	*Acidification (% area at risk)*	*AAE Acidification (mol $H^+.ha^{-1}.yr^{-1}$)*	*Eutrophication (% area at risk)*	*AAE Eutrophication (mol $N.ha^{-1}.yr^{-1}$)*	*Bio-diversity, as species richness in grasslands (%)*	*Wheat yield reduction ozone (%)*	*Materials corrosion (% area of country at significant risk)*	*Materials soiling (% area of country at significant risk)*
Poland	9	40	672	46	243	74	328	77	14	99	58
Portugal	8	48	425	2	3	100	264	90	11	24	27
Republic of Moldova	9	68	583	1	2	100	407	84	—	40	7
Romania	11	69	879	3	11	99	493	79	12	71	47
Russian Federation	7	52	482	2	2	48	78		—	3	0
Slovakia	9	52	872	10	45	98	524	80	13	96	60
Slovenia	9	62	771	2	5	91	265	72	13	86	47
Spain	7	41	338	1	4	99	400	86	9	13	7
Sweden	3	24	308	12	18	36	62	87	9	2	0
Switzerland	7	48	604	12	52	75	579	61	6	28	15
The former Yugoslav Republic of Macedonia	7	64	699	11	39	91	280	85	—	53	7
Turkey	—	—	0	—	—	—	—	—	—	8	10
Ukraine	9	81	704	2	4	100	520	83	—	34	22
United Kingdom	6	18	255	14	37	53	170	80	6	80	49
Subtotal (EU-28)	**8**	**45**	**651**	**10**	**39**	**67**	**280**	**78**	**12**	**47**	**34**
Subtotal (Non-EU)[b]	**7**	**58**	**420**	**3**	**6**	**60**	**152**	**81[c]**	**—**	**9**	**4**
Total	**8**	**49**	**565**	**7**	**22**	**57**	**190**	**78[c]**	**11**	**25**	**17**

[a] Missing Parties or data indicate this information is not available.
[b] Including Serbia and Montenegro.
[c] Excluding areas east of 32°E.

Table 2
Health and environmental indicator values for effects of emissions in 2020[a]

Party	*Mortality PM (average months lost per person)*	*Mortality ozone (cases. yr^{-1} per million people)*	*Morbidity PM and ozone (cases.yr^{-1} per million people)*	*Acidification (% area at risk)*	*AAE Acidification (mol $H^{+}.ha^{-1}.yr^{-1}$)*	*Eutrophication (% area at risk)*	*AAE Eutrophication (mol $N.ha^{-1}.yr^{-1}$)*	*Bio-diversity, as species richness in grasslands*	*Wheat yield reduction ozone (%)*	*Material corrosion (% area of country at significant risk)*	*Materials soiling (% area of country at significant risk)*
Albania	6	37	552	0	0	81	218	82		67	0
Austria	5	40	865	0	0	51	134	72	7	7	0
Belarus	6	40	399	6	10	100	397	83	—	1	0
Belgium	7	24	385	1	3	1	1	70	11	78	60
Bosnia and Herzegovina	5	47	545	2	1	67	131	85	—	11	0
Bulgaria	8	80	776	0	0	38	52	86	10	10	1
Croatia	6	58	470	2	3	82	262	84	—	11	0
Cyprus	6	38	181	0	0	100	243	—	—	0	49
Czech Republic	6	37	606	50	123	80	229	80	11	31	1
Denmark	4	23	284	1	2	99	365	82	9	1	1
Estonia	4	22	310	0	0	18	16	91	10	0	0
Finland	3	14	297	0	0	3	1	95	6	0	0
France	6	27	402	3	3	74	230	79	10	8	6
Germany	5	33	695	5	13	46	218	71	11	48	9
Greece	8	55	718	1	1	95	219	89	10	5	9
Hungary	8	61	858	5	11	90	370	81	12	27	2
Ireland	2	12	139	0	0	11	14	85	4	1	2
Italy	8	67	761	0	1	48	195	82	12	19	15
Latvia	5	31	440	3	3	75	112	89	10	0	0
Liechtenstein	—	—	0	0	0	100	288	81	—	—	—
Lithuania	5	32	612	30	86	97	318	84	11	0	0
Luxembourg	7	26	520	12	32	97	504	77	11	45	2
Malta	6	50	533	—	—	—	—	—	14	0	100
Netherlands	5	20	298	63	518	85	559	65	9	87	72

Party	*Mortality PM (average months lost per person)*	*Mortality ozone (cases. yr^{-1} per million people)*	*Morbidity PM and ozone (cases.yr^{-1} per million people)*	*Acidification (% area at risk)*	*AAE Acidification (mol $H^{+}.ha^{-1}.yr^{-1}$)*	*Eutrophication (% area at risk)*	*AAE Eutrophication (mol $N.ha^{-1}.yr^{-1}$)*	*Bio-diversity, as species richness in grasslands*	*Wheat yield reduction ozone (%)*	*Material corrosion (% area of country at significant risk)*	*Materials soiling (% area of country at significant risk)*
Norway	2	16	222	2	1	1	1	93	3	1	0
Poland	7	32	524	24	74	64	223	79	11	76	7
Portugal	5	40	320	0	1	99	194	90	10	1	6
Republic of Moldova	7	58	491	0	0	100	309	85	—	0	0
Romania	8	54	645	0	0	92	269	84	10	2	0
Russian Federation	7	48	456	0	0	40	52	—	—	3	0
Slovakia	7	41	652	3	6	89	287	84	10	11	0
Slovenia	7	47	577	0	0	34	42	78	10	18	0
Spain	4	33	246	0	0	95	273	88	8	4	0
Sweden	2	18	234	6	4	19	19	90	7	0	0
Switzerland	5	37	446	5	18	66	403	65	5	10	0
The former Yugoslav Republic of Macedonia	6	53	571	0	0	73	151	89	—	25	0
Turkey	—	—	0	—	—	—	—	—	—	9	12
Ukraine	8	72	633	0	0	100	424	84	—	22	13
United Kingdom	4	18	205	3	6	27	38	84	5	31	4
Subtotal (EU-28)	**6**	**36**	**499**	**4**	**9**	**54**	**159**	**81**	**10**	**17**	**5**
Subtotal (Non EU)[b]	**7**	**52**	**380**	**1**	**1**	**55**	**135**	**84[c]**	**—**	**6**	**3**
Total	**6**	**41**	**455**	**2**	**5**	**47**	**117**	**82[c]**	**9**	**11**	**4**

[a] Missing Parties or data indicate that this information is not available.
[b] Including Serbia and Montenegro.
[c] Excluding areas east of 32°E.

Table 3

Relative environmental and health improvements in 2020 (table 2) compared with the year 2005 (table 1)[a]

Party	*Mortality PM (%)*	*Mortality ozone (%)*	*Morbidity PM and ozone (%)*	*Acidification (%)*	*AAE Acidification (%)*	*Eutrophication (%)*	*AAE Eutrophication (%)*	*Biodiversity, as species richness in grasslands*	*Wheat yield reduction ozone (%)*	*Materials corrosion (%)*	*Materials soiling (%)*
Albania	16	17	17	100	100	12	25	2	—	26	100
Austria	25	20	22	100	100	37	57	7	25	85	100
Belarus	16	17	17	58	73	0	14	1	—	82	—
Belgium	30	2	19	93	95	87	92	8	9	22	40
Bosnia and Herzegovina	15	22	19	87	98	8	44	5	—	70	100
Bulgaria	31	20	25	—	—	50	68	3	16	89	98
Croatia	24	24	24	60	92	14	48	7	—	84	100
Cyprus	5	22	14	—	—	0	14	—	—	—	0
Czech Republic	25	20	22	41	77	15	56	7	20	68	97
Denmark	35	14	23	98	98	1	49	9	17	99	98
Estonia	18	19	19	100	100	53	59	3	18	100	—
Finland	26	22	24	100	100	71	83	2	21	—	—
France	31	23	28	71	91	17	47	5	20	79	86
Germany	27	15	21	82	85	19	42	7	17	51	87
Greece	37	13	26	76	94	5	42	5	11	88	80
Hungary	25	22	24	79	88	10	45	7	21	73	98
Ireland	30	9	20	93	95	55	64	3	17	84	58
Italy	25	21	23	89	85	35	47	5	20	54	62
Latvia	18	22	19	78	89	19	44	3	18	100	—
Liechtenstein	—	—	—	100	100	0	37	5	—	—	—
Lithuania	20	21	21	13	50	1	19	2	18	100	—
Luxembourg	29	19	27	15	69	3	31	5	17	55	98
Malta	33	16	24	—	—	—	—	—	9	100	0
Netherlands	33	–3	21	19	57	5	42	11	7	13	28
Norway	22	20	20	79	89	77	88	3	21	65	44

Party	Mortality PM (%)	Mortality ozone (%)	Morbidity PM and ozone (%)	Acidification (%)	AAE Acidification (%)	Eutrophication (%)	AAE Eutrophication (%)	Biodiversity, as species richness in grasslands	Wheat yield reduction ozone (%)	Materials corrosion (%)	Materials soiling (%)
Poland	23	21	22	49	69	13	32	3	18	24	87
Portugal	30	16	25	78	70	1	26	1	11	97	79
Republic of Moldova	16	15	16	100	100	0	24	2	—	100	100
Romania	31	22	27	96	99	7	45	6	17	97	99
Russian Federation	4	7	5	82	88	18	34		—	13	26
Slovakia	28	22	25	68	88	10	45	6	22	89	100
Slovenia	27	24	25	97	98	63	84	8	24	80	100
Spain	34	18	27	98	99	4	32	3	15	67	94
Sweden	27	22	24	53	77	48	69	4	20	92	—
Switzerland	30	24	26	57	64	11	30	6	24	65	100
The former Yugoslav Republic of Macedonia	20	17	18	100	100	19	46	4	—	53	100
Turkey	—	—	—	—	—	—	—	—	—	–14	–21
Ukraine	9	12	10	93	98	0	18	1	—	35	40
United Kingdom	35	–4	20	75	85	49	78	5	11	61	92
Subtotal (EU–28)	**29**	**18**	**23**	**62**	**76**	**19**	**43**	**4**	**18**	**63**	**86**
Subtotal (Non-EU)[b]	**8**	**10**	**9**	**1**	**1**	**8**	**11**	**3[c]**		**34**	**33**
Total	**23**	**15**	**19**	**67**	**78**	**17**	**39**	**4[c]**	**18**	**57**	**77**

[a] Missing Parties or data indicate that this information is not available.
[b] Including Serbia and Montenegro.
[c] Excluding areas east of 32°E.

References

Amann, Markus, and others (2011). Cost-effective control of air quality and greenhouse gases in Europe: Modeling and policy applications. *Environmental Modelling and Software*, vol. 26, No. 12 (December 2011), pp. 1489-1501. Available from http://dx.doi.org/10.1016/j.envsoft.2011.07.012.

Amann, Markus and others, eds. (2013). *Policy scenarios for the revision of the Thematic Strategy on Air Pollution*. TSAP Report No. 10, Version 1.2. Laxenburg, Austria: IIASA, March 2013. Available from http://ec.europa.eu/environment/air/pdf/TSAP-Report-10.pdf.

CLRTAP (2013). Manual on methodologies and criteria for modelling and mapping critical loads and levels and air pollution effects, risks and trends, ECE Convention on Long-range Transboundary Air Pollution; accessed on 26 September 2013 at www.icpmapping.org.

Hettelingh, J.-P., M. Posch and J. Slootweg, eds. (2009). *Progress in the modelling of critical thresholds, impacts to plant species diversity and ecosystem services in Europe: CCE Status Report 2009*. Bilthoven, the Netherlands: Coordination Centre for Effects. Available from http://www.wge-cce.org/Publications/CCE_Status_Reports/Status_Report_2009.

Hettelingh, J.-P., and others (forthcoming). Assessing the impacts of nitrogen deposition on indicator values of plant species in Europe. Springer Publishing.

Katsoyanni, Klea and Jonathan M. Samet (2009). *Air Pollution and Health: A European and North American Approach (APHENA).* Research Report 142. Boston, Massachussets: Health Effects Institute.

Kucera, Vladimir, and others (2007). UN/ECE ICP Materials Dose-response Functions for the Multi-pollutant Situation. *Water, Air, and Soil Pollution: Focus*, vol. 7, Nos. 1–3, pp. 249–258.

Mills, G., and H. Harmens (2011). *Ozone pollution: A hidden threat to food security*. Bangor, United Kingdom: ICP Vegetation Programme Coordination Centre. Available from http://icpvegetation.ceh.ac.uk.

Mills, G., and others (2011). New stomatal flux-based critical levels for ozone effects on vegetation. *Atmospheric Environment*, vol. 45, pp. 5064–5068.

Mills, G., and others (2013). *Ozone pollution: Impacts on ecosystem services and biodiversity*. Bangor, United Kingdom: ICP Vegetation Programme Coordination Centre. Available from http://icpvegetation.ceh.ac.uk.

New, Mark, and others (2002). A high-resolution data set of surface climate over global land areas. *Climate Research*, vol. 21, pp. 1–25.

Posch, M., J. Slootweg and J.-P. Hettelingh, eds. (2012). *Modelling and Mapping of Atmospherically-induced Ecosystem Impacts in Europe*. CCE Status Report 2012. Bilthoven, the Netherlands, Coordination Centre for Effects.

Posch, M., J.-P. Hettelingh and P. A. M. De Smet (2001). Characterization of critical load exceedances in Europe. *Water, Air and Soil Pollution*, vol. 130, Nos. 1–4 (August), pp. 1139–1144.

Stevens, Carly J., and others (2010). Contribution of acidification and eutrophication to declines in species richness of calcifuge grasslands along a gradient of atmospheric nitrogen deposition. *Functional Ecology*, vol. 24, No. 2 (April) pp. 478–484.

Watt, John, and others (2009). Soiling. In *The Effects of Air Pollution on Cultural Heritage.* New York, Springer Publishing.

Working Group on Effects (2013), Benefits of Air pollution control for biodiversity and ecosystem services, (ECE/EB.AIR/WG.1/2013/14).

World Health Organization (2013a), Review of evidence on health aspects of air pollution – REVIHAAP Project: Final technical report. Copenhagen, WHO Regional Office for Europe. Available from http://www.euro.who.int/en/what-we-do/health-topics/environment-and-health/air-quality/publications/2013/review-of-evidence-on-health-aspects-of-air-pollution-revihaap-project-final-technical-report.

World Health Organization (2013b), Concentration-response functions for cost-benefit analysis of particulate matter, ozone and nitrogen dioxide, Health Risks of Air Pollution in Europe (HRAPIE), draft report. 5 August 2013.

World Health Organization (2013c). European Hospital Morbidity Database: WHO Regional Office for Europe. Available from http://data.euro.who.int/hmdb/index.php.

United Nations Economic Commission for Europe (2007). Report of the Executive Body on its twenty-fifth session (ECE/EB.AIR/91).

United Nations Economic Commission for Europe (2008). Draft guidelines for reporting on the monitoring and modelling of air pollution effects (ECE/EB.AIR/WG.1/2008/16).

United Nations Economic Commission for Europe (2012a). Parties to UNECE Air Pollution Convention approve new emission reduction commitments for main air pollutants by 2020. Press release of 4 May 2012, available from http://www.unece.org/index.php?id=29858.

United Nations Economic Commission for Europe (2012b). Decision 2012/2 of the Executive Body (see ECE/EB.AIR/113/Add.1). Available from http://www.unece.org/env/lrtap/executivebody/eb_decision.html.

United Nations Economic Commission for Europe (2012c). Decisions 2012/1 and 2012/2 of the Executive Body (see ECE/EB.AIR/111/Add.1). Available from http://www.unece.org/env/lrtap/executivebody/eb_decision.html.