10 Health impacts of exposure to fine particulate matter, nitrogen dioxide and ozone

The health impacts of air pollution can be quantified and expressed as premature mortality and morbidity. Mortality reflects reduction in life expectancy owing to premature death as a result of air pollution exposure, whereas morbidity relates to occurrence of illness and years lived with a disease or disability, ranging from subclinical effects to chronic conditions that may require hospitalisation. Even less severe effects might have strong public health implications, because air pollution affects the whole population on a daily basis, especially in major cities where concentrations tend to be higher than in rural areas (with the exception of ozone). Most of the evidence on the health impacts of pollution tends to focus on premature mortality, as well as respiratory, cardiovascular and cerebrovascular effects attributed to exposure to air pollution (WHO, 2008, 2013b), but evidence also exists of a range of other effects.

The health impacts from air pollution can be estimated using different health outcomes (Box 10.1). The health impacts estimated for this report are those attributable to exposure to $PM_{2.5}$, NO_2 and O_3 in Europe for 2013 ([41]). This assessment required information on air pollution, demographic data and the relationship between exposure to ambient pollutant concentrations and a health outcome. The maps of air pollutant concentrations (annual mean concentration for $PM_{2.5}$ and NO_2, and SOMO35 for O_3; ETC/ACM, 2016b) are based on the Air Quality e-Reporting Database (EEA, 2016a) monitoring data measured at regional and urban background stations in 2013, auxiliary information, such as meteorological data, and concentrations modelled with the EMEP chemical dispersion model. The demographic data and the health-related data were taken from the United Nations (UN, 2015) and the WHO (2016), respectively. The exposure–response relation and the population at risk have been selected in accordance with the recommendation given by the Health Risks of Air Pollution in Europe (HRAPIE) project (WHO, 2013b). For $PM_{2.5}$, impacts have been estimated for the full range of observed concentrations, meaning all $PM_{2.5}$ is considered, even that of natural origin; for NO_2, impacts have been estimated for levels above 20 µg/m^3 ([42]). A further description and details on the methodology are given by the ETC/ACM (2016c).

The results of the health impact assessment are presented in Tables 10.1 and 10.2 for 41 European countries, for the 41 counties as a whole ('Total') and for the EU-28. Table 10.1 presents, for each pollutant, the population-weighted concentration and the estimated number of premature deaths, in addition to the population for each country for

Box 10.1 Different ways of estimating health impacts

Premature deaths are deaths that occur before a person reaches an expected age. This expected age is typically the age of standard life expectancy for a country and gender. Premature deaths are considered to be preventable if their cause can be eliminated.

Years of life lost (YLL) are defined as the years of potential life lost owing to premature death. It is an estimate of the average years that a person would have lived if he or she had not died prematurely. YLL take into account the age at which deaths occur, giving greater weight to deaths at a younger age and lower weight to deaths at an older age. It gives, therefore, more nuanced information than the number of premature deaths alone.

([41]) In the methodology used, the air pollutant concentrations are obtained from interpolated maps. To produce these maps, information from the EMEP model is needed and at the time of drafting this report the most up-to-date data from the EMEP model were from 2013 (ETC/ACM, 2016c)

([42]) The studies in HRAPIE showed that for NO_2 the size of the effect is less certain below 20 µg/m^3. However, this recommendation might be too conservative (Héroux et al., 2015) and there is continued work to provide more guidance on this.

comparison between countries. In the 41 countries listed, 467 000 premature deaths are attributed to $PM_{2.5}$ exposure, 71 000 to NO_2 exposure and 17 000 to O_3 exposure. In the EU-28, the premature deaths attributed to $PM_{2.5}$, NO_2 and O_3 exposure are 436 000, 68 000 and 16 000, respectively ([43]).

Table 10.2 presents the estimated number of years of life lost (YLL) and the YLL per 100 000 inhabitants due to exposure to $PM_{2.5}$, NO_2 and O_3 in Europe for 2013. In total, in the 41 countries assessed, 4 982 000 YLL are attributed to $PM_{2.5}$ exposure, 756 000 YLL to NO_2 exposure and 192 000 YLL to O_3 exposure. In the EU-28, the YLL attributed to $PM_{2.5}$, NO_2 and O_3 exposure are 4 668 000, 723 000 and 179 000, respectively ([44]).

For $PM_{2.5}$, the highest numbers of YLL are estimated for the countries with the largest populations (Germany, Italy, France and the United Kingdom). However, in relative terms, when considering YLL per 100 000 inhabitants, the largest impacts are observed in the central and eastern European countries where the highest concentrations are also observed, i.e. Kosovo under the UN SCR 1244/99, Bulgaria, the former Yugoslav Republic of Macedonia, Poland, Serbia, Hungary, Romania, Greece, the Czech Republic and Slovakia.

The largest health impacts attributable to NO_2 exposure are seen in Italy, the United Kingdom, Germany and France. When considering YLL per 100 000 inhabitants, the highest rates are found in Italy, Belgium, the United Kingdom and Serbia.

Regarding O_3, the countries with the largest impacts are Italy, Germany, France, Spain and Poland; and the countries with the highest rates of YLL per 100 000 inhabitants are Greece, Italy, most of the countries in the Western Balkans and Hungary.

The impacts estimated for each pollutant may not be added to determine the total impact attributable to exposure to these three pollutants, because concentrations are (sometimes strongly) correlated. This may lead to a double counting of up to 30 % of the effects of $PM_{2.5}$ and NO_2 (WHO, 2013b). This possible double counting has not been corrected for.

Variations from one year to another are proportional, in the case of $PM_{2.5}$, to the changes in population and weighted-population concentrations. This is not the case for NO_2, for which only concentrations above 20 µg/m^3 are considered. In this case, the most determining factor is the percentage of the population exposed to levels above 20 µg/m^3.

([43]) These figures have the following confidence intervals (CIs; the CI gives the upper and lower boundaries of the 95 % confidence interval of the estimate taking into account only the uncertainty in the relative risk):
- for premature deaths in all the countries attributed to $PM_{2.5}$, 310 000–608 000; to NO_2, 41 000–102 000; and to O_3, 8 000–26 000;
- for premature deaths in the EU-28 attributed to $PM_{2.5}$, 289 000–569 000; to NO_2, 39 000–97 000; and to O_3, 8 000–24 000.

([44]) With the following CIs:
- for YLL in all the countries attributed to $PM_{2.5}$, 3 307 000–6 495 000; to NO_2, 436 000–1 077 000; and to O_3, 93 000–284 000;
- for YLL in the EU-28 attributed to $PM_{2.5}$, 3 098 000–6 087 000; to NO_2, 417 000–1 030 000; and to O_3, 86 000–265 000.

Table 10.1 Premature deaths attributable to $PM_{2.5}$, NO_2 and O_3 exposure in 41 European countries and the EU-28 in 2013

Country	Population	$PM_{2.5}$		NO_2		O_3	
		Annual mean ([c])	Premature deaths	Annual mean ([c])	Premature deaths	SOMO35 ([c])	Premature deaths
Austria	8 451 860	15.7	6 960	19.3	910	5 389	330
Belgium	11 161 642	16.6	10 050	23.6	2 320	2 520	210
Bulgaria	7 284 552	24.1	13 700	16.5	570	4 082	330
Croatia	4 262 140	16.8	4 820	15.8	160	5 989	240
Cyprus	865 878	17.1	450	7.3	< 5	7 900	30
Czech Republic	10 516 125	19.6	12 030	17.1	330	4 266	370
Denmark	5 602 628	9.6	2 890	13.0	60	2 749	110
Estonia	1 320 174	7.8	690	10.8	< 5	2 545	30
Finland	5 426 674	5.9	1 730	9.4	< 5	2 011	80
France	63 697 865	14.5	45 120	18.7	8 230	4 098	1 780
Germany	80 523 746	14.2	73 400	20.4	10 610	3 506	2 500
Greece	11 003 615	19.7	13 730	14.6	1 490	8 532	840
Hungary	9 908 798	18.2	12 890	16.8	390	4 604	460
Ireland	4 591 087	9.2	1 520	11.6	30	2 043	50
Italy	59 685 227	18.2	66 630	24.5	21 040	6 576	3 380
Latvia	2 023 825	12.8	2 080	13.7	110	2 614	60
Lithuania	2 971 905	13.9	3 170	11.5	< 5	2 703	90
Luxembourg	537 039	14.3	280	23.4	80	3 167	10
Malta	421 364	12.5	230	12.0	< 5	7 403	20
Netherlands	16 779 575	14.3	11 530	21.3	1 820	2 410	270
Poland	38 062 535	22.8	48 270	16.1	1 610	3 792	1 150
Portugal	9 918 548	10.0	6 070	14.0	150	5 091	420
Romania	20 020 074	18.5	25 330	17.9	1 900	2 221	430
Slovakia	5 410 836	20.1	5 620	16.0	< 5	5 116	200
Slovenia	2 058 821	17.4	1 960	17.6	150	6 540	100
Spain	44 454 505	11.0	23 940	18.0	4 280	5 895	1 760
Sweden	9 555 893	6.0	3 020	11.5	< 5	2 317	160
United Kingdom	63 905 297	11.8	37 930	22.8	11 940	1 606	710
Albania	2 874 545	20.3	2 010	15.9	10	7 179	100
Andorra	76 246	11.9	40	14.3	< 5	7 303	< 5
Bosnia and Herzegovina	3 839 265	16.0	3 620	15.7	80	5 670	180
former Yugoslav Republic of Macedonia	2 062 294	30.4	3 360	20.8	210	6 326	100
Iceland	321 857	6.5	80	14.3	< 5	1 473	< 5
Kosovo ([a])	1 815 606	28.0	3 530	19.3	230	5 691	100
Liechtenstein	36 838	11.4	20	22.7	10	5 221	< 5
Monaco	36 136	13.8	20	23.2	10	7 795	< 5
Montenegro	620 893	17.1	600	17.2	30	6 674	30
Norway	5 051 275	7.1	1 590	14.4	170	2 443	70
San Marino	33 562	15.1	30	15.4	< 5	5 067	< 5
Serbia	7 181 505	21.1	10 730	20.2	1 340	4 505	320
Switzerland	8 039 060	13.9	4 980	22.4	1 140	4 919	240
Total ([b])			**467 000**		**71 000**		**17 000**
EU-28 ([b])			**436 000**		**68 000**		**16 000**

Notes: ([a]) Under the UN Security Council Resolution 1244/99.

([b]) Total and EU-28 figures are rounded up or down to the nearest thousand. The national totals to the nearest ten.

([c]) The annual mean (in µg/m³) and the SOMO35 (in (µg/m³).day), expressed as population-weighted concentration, is obtained according to the methodology described by ETC/ACM (2016b), and not only from monitoring stations.

Table 10.2 Years of life lost (YLL) attributable to $PM_{2.5}$, NO_2 and O_3 exposure in 41 European countries and the EU-28 in 2013

Country	$PM_{2.5}$		NO_2		O_3	
	YLL	YLL/100 000 inhabitants	YLL	YLL/100 000 inhabitants	YLL	YLL/100 000 inhabitants
Austria	72 600	859	9 500	112	3 600	43
Belgium	103 600	928	23 900	214	2 300	21
Bulgaria	136 500	1 874	5 700	78	3 500	48
Croatia	47 800	1 122	1 600	37	2 500	58
Cyprus	4 700	540	< 10	0	300	37
Czech Republic	129 600	1 233	3 600	34	4 100	39
Denmark	31 600	563	600	12	1 300	23
Estonia	7 300	556	< 10	0	300	25
Finland	18 300	337	< 10	0	900	16
France	504 000	791	91 900	144	20 900	33
Germany	759 000	943	109 700	136	27 200	33
Greece	135 900	1 235	14 700	134	8 600	78
Hungary	138 700	1 400	4 200	42	5 100	51
Ireland	17 300	376	300	6	600	12
Italy	695 500	1 165	219 700	368	36 500	61
Latvia	22 000	1 085	1 200	57	600	32
Lithuania	31 600	1 063	< 10	0	900	30
Luxembourg	3 100	585	800	157	100	19
Malta	2 400	571	< 10	0	200	50
Netherlands	125 200	746	19 800	118	3 100	18
Poland	578 500	1 520	19 300	51	14 400	38
Portugal	62 700	632	1 600	16	4 500	45
Romania	265 700	1 327	19 900	100	4 800	24
Slovakia	63 100	1 167	< 10	0	2 400	45
Slovenia	21 400	1 037	1 700	80	1 200	56
Spain	253 100	569	45 300	102	19 300	43
Sweden	29 400	307	< 10	0	1 600	17
United Kingdom	407 400	637	128 300	201	8 100	13
Albania	21 000	730	100	3	1 200	43
Andorra	500	658	< 10	0	< 100	59
Bosnia and Herzegovina	38 700	1 007	900	23	2 000	52
former Yugoslav Republic of Macedonia	35 800	1 734	2 200	109	1 200	57
Iceland	900	269	< 10	0	< 100	9
Kosovo [a]	35 100	1 935	2 300	128	1 100	60
Liechtenstein	200	632	< 100	159	< 100	42
Monaco	300	760	< 100	160	< 100	62
Montenegro	6 700	1 083	300	52	400	64
Norway	16 200	321	1 700	34	800	16
San Marino	300	979	< 10	0	< 100	47
Serbia	107 000	1 490	13 400	186	3 400	47
Switzerland	51 400	639	11 700	146	2 700	33
Total [b]	**4 982 000**		**756 000**		**192 000**	
EU-28 [b]	**4 668 000**		**723 000**		**179 000**	

Note: YLL and YLL per 100 000 inhabitants: all-cause mortality.

[a] Under the UN Security Council Resolution 1244/99.

[b] Total and EU-28 figures are rounded up or down to the nearest thousand. YLL are rounded to the next hundred.