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Burden of disease attributable to selected environmental factors and injuries among Europe's children and adolescents

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Preface

The disease burden of a population, and how that burden is distributed across different subpopulations (e.g. infants, women), are important pieces of information for defining strategies to improve population health. For policy-makers, disease burden estimates provide an indication of the health gains that could be achieved by targeted action against specific risk factors. The measures also allow policy-makers to prioritize actions and direct them to the population groups at highest risk. To help provide a reliable source of information for policy-makers, WHO recently analysed 26 risk factors worldwide, including some environmental risk factors, in the World Health Report (WHO, 2002). The Environmental Burden of Disease (EBD) series of guides continues this effort to generate reliable information, and most of the guides provide step-by-step practical assistance on how to assess the environmental burden of disease at national and local levels.

In this guide, we use the Global Burden of Disease methodology (WHO, 2001) to estimate the burden of childhood disease and injury attributable to selected environmental risks in the WHO European Region. The study was carried out by the WHO Regional Office for Europe, European Centre for Environment and Health, Rome Office, through the Institute of Hygiene and Epidemiology, University of Udine and the Institute of Child Health "Burlo Garofolo" in Trieste, Italy, to serve as the basis for the Children's Environment and Health Action Plan for Europe (CEHAPE), which is to be adopted at the Fourth Ministerial Conference on Environment and Health, Budapest, Hungary, 23–25 June 2004.

Environmental exposures are known to be important contributors to the global burden of disease among children and adolescents, but there are still gaps in our knowledge about the magnitude and regional distribution of the environmental burden among the young. This investigation is the first attempt to assess the overall impact of the environment on child health in the European Region, and to highlight the number of lives (and disabilities) that could be saved by reducing the exposure of children to these hazards. The results indicate that indoor and outdoor air pollution, unsafe water conditions, lead exposure and injuries account for about one third of the total burden of disease in 0–19 year old children, and that substantial public-health gains could result from action aimed at reducing the exposure of children to these environmental risk factors and at preventing injuries.

Based on the results of this study, four Regional priority goals have been proposed for CEHAPE. They are to confront the health burden arising from: 1) lack of adequate water and sanitation; 2) mobility-related and transportation-related injuries, as well as unintentional injuries; 3) indoor and outdoor air pollution; and 4) hazardous chemicals and occupational hazards. In many cases, effective actions for addressing these risk factors exist. Multisectoral approaches, including engineering, educational and law enforcement interventions, have been shown to reduce the incidence of injury and the severity of the consequences. Phasing out lead from gasoline also has proved to be effective at reducing mild mental retardation, cognitive disorders and behavioural problems associated with elevated blood lead levels. And improvement of water quality has a dramatic effect on the health and survival of young children. The four

CEHAPE priorities are to be adopted at the Fourth Ministerial Conference on Environment and Health, in Budapest, Hungary 23–25 June 2004.

The ministerial conference is one in a series that started in Frankfurt in 1989, with the aim of promoting a European-wide political and public-health process on environmental health. Recognizing that environmental health risks cannot be addressed without involving different sectors, these conferences facilitate dialogue and joint action among different stakeholders, and put health firmly on the agenda of environment, transportation and research authorities at different levels of decision-making in Europe. The ministerial conferences in the series have addressed different issues: principles and strategies (in Frankfurt, 1989); situation assessment in national plans (in Helsinki, 1994); action in partnership (in London, 1999); and vulnerable groups (in Budapest, 2004).

We hope the results of this study will serve as a foundation for further EBD studies, and encourage countries to initiate their own. The results would allow preventive actions to be better targeted, and could be used to assess progress in public health. A summary of this report has also been published in: Valent F, Little D, Bertollini R, Nemer LE, Barbone F, Tamburlini G. Burden of disease attributable to selected environmental factors and injury among children and adolescents in Europe. Lancet 2004; 363:2032-39.

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In preparing this document the authors drew on methods from the Environmental Burden of Disease developed by the WHO Protection of the Human Environment department, and would therefore like to thank them for their review of this analysis. We would also like to thank J.A. Vincenten and M. Sector, European from the Child Safety Alliance (ECOSA), for reviewing the injury section, as well as Philip Landrigan in the Department of Community and Preventive Medicine, Mount Sinai School of Medicine, for his review.

List of abbreviations

AB	Attributable burden
ALRI	Acute lower respiratory infections
AF	Attributable fraction
ARI	Acute respiratory infections
BLL	Blood lead level
CI	Confidence interval
DALY	Disability-adjusted life year
EBD	Environmental burden of disease
EU	European Union
ICD	International classification of diseases
IQ	Intelligence quotient
MMR	Mild mental retardation
NIS	Newly independent states
PM	Particulate matter
SFU	Solid fuel use
YLD	Years lived with disability
YLL	Years of life lost due to premature mortality
WHO	World Health Organization

Summary

Although exposures to environmental risks contribute significantly to the burden of disease among children and adolescents (Smith, Corvalan & Kjellstrom, 1999; WHO, 2002), there are still gaps in our knowledge about the magnitude and regional distribution of the environmental burden of disease (EBD) among the young. For the WHO European Region in particular, there are no estimates. This study aims to estimate the burden of childhood disease and injury attributable to environmental risks in the WHO European Region, as well as the health gains that could be achieved by reducing the exposure of the child population to these risks.

We analysed five environmental risks factors:

- outdoor air pollution
- indoor air pollution
- water, sanitation, and hygiene
- lead
- injury.

The burden of disease was measured in terms of the disability-adjusted life year (DALY), a summary measure that accounts for the impact both of "premature" death (i.e. the years of life lost due to premature death, or YLL), and of health problems among those who are alive (i.e. the number of years lived with a disability, or YLD). For the purpose of this study, we also considered the environment in a broad sense, and included both the physical and socioeconomic settings. For this reason, we present the burden of all injuries, not just those directly attributable to the physical environment, such as occupational or domestic hazards. The methods used to estimate the burden of child disease attributable to each risk factor are described separately for each risk factor, and are consistent with those developed by WHO for the Global Burden of Disease (GBD) study (WHO, 2000a). Since patterns of morbidity and mortality vary across the European Region, and environmental factors are likely to be at least partly responsible for such differences, the analyses were performed separately for each of the three WHO European subregions, EUR A, EUR B, and EUR C (see Annex 1 for a list of the Member States in each subregion and for a description of the inclusion criteria). This follows the classification used by WHO (WHO-CHOICE, 2003).

The year 2001 was chosen as the reference year because it ensured a good balance between availability of data and timeliness. Age groups included in the analyses were 0–4, 5–14 and 15–19 years. The age group 15–19 years was used so as to include the entire adolescent population and ensure comparability with other studies. Due to the limited availability of complete data on exposures and health effects in all age groups, estimates of the disease burden attributable to certain risk factors did not include the complete child age range (0–19 years) and should therefore be considered conservative.

The burden of disease attributable to the five environmental risks accounted for one third of the total disease burden for children 0–19 years of age in the EUR Region. Among children 0–4 years of age, the five risks contributed to 21.9–26.5% of all deaths and to 19.8% of all DALYs. Among those 5−14 years old, the risks contributed to 42.1% of all deaths and to 30.8% of all DALYs. Among those 15−19 years old, the risks were responsible for 59.9% of all deaths and for 27.1% of all DALYs. Children living in EUR B and EUR C suffered the most from exposures to the environmental risk factors. Injuries were the leading cause of deaths and DALYs in all age groups in EUR A and among children and adolescents 5−14 years old and 15−19 years old in EUR B and EUR C.

Given the scarcity of published and available literature from certain countries, results of this study may be skewed towards those with available data. More uniform and widespread collection of environmental exposure data, as well as regional standardization and routine collection of morbidity and mortality statistics, are needed to improved burden of disease estimates.

1. Outdoor air pollution

1.1 Introduction

Each year, outdoor air pollution causes an estimated 800 000 deaths from lung cancer, cardiovascular and respiratory diseases worldwide. It also increases the incidence of chronic bronchitis and acute respiratory illness, exacerbates asthma and coronary disease, and impairs lung function (World Bank, 2003a). In children, outdoor air pollution has been associated with a variety of health effects, including increased morbidity and mortality from acute lower respiratory infections (ALRI) (Bobak & Leon, 1992; Smith et al., 2000), an increased incidence of exacerbated asthma (Roemer W, Hoek G, Brunekreef, 1993; Gielen et al., 1997; Segala et al., 1998; Kunzli et al., 1999; van der Zee et al., 1999; Chauhan et al., 2003), low birth weight (Dejmek et al., 2000; Rogers et al., 2000) and congenital anomalies (Perere et al., 1998).

The most significant health effects of outdoor air pollution have been associated with particulate matter (PM) and, to a lesser extent, ground-level ozone. Although the largest health impacts of PM are associated with particles smaller than 10 µm in diameter (PM10), which can penetrate deep into the respiratory tract, smaller particles (e.g. those 2.5 µm in diameter) are of more concern because of their greater potential for penetration. In Europe, several sources are responsible for airborne particulate emissions. Anthropogenic sources include: vehicles; stationary combustion sources, such as houses that burn coal for domestic purposes, industrial plants, incinerators, waste disposal plants, and fossil-fuel power plants; non-combustion sources, such as construction, quarrying and mining, cement plants and the ceramics industry; and forest and agricultural fires. Natural sources include the soil (when it is dispersed into the air), sea spray, dust carried long distances in air, and volcano emissions (ECTWG, 2003).

1.2 Methods

We calculated the burden of all-cause mortality for children 0–4 years of age that was attributable to short-term exposure to outdoor air pollution. Outdoor air pollution was expressed as the mean PM10 concentration for each of the EUR subregions. The subregional means were obtained from country PM10 concentrations that were weighted by the country population in the age group under study (UNPD, 2002). Two sets of exposure data were used to calculate the mortality burden. The first was the average PM10 concentrations estimated by the World Bank for almost every country. The data are based on a model that includes demographics, energy consumption, level of economic development, geographical and meteorological variables, and available PM monitoring measurements worldwide (World Bank, 2003b). The second data set was derived from epidemiological studies that measured PM10 concentrations at fixed-site monitors in the last 10 years (Hoek et al., 1997; Pekkanen et al., 1997; Cerna et al., 1998; Brauer et al., 2000; Junker et al., 2000; Kingham et al., 2000; Kunzli et al., 2000; Larssen et al., 2000; van der Wal & Janssen, 2000; Biggeri, Bellini & Terracini, 2001; Howel, Darnell & Pless-Mulloli, 2001; Marcazzan et al., 2001; Querol et al., 2001; EEA, 2003; Naef & Xhillari, 2003; Peacock et al., 2003; Sokhi et al., 2003).

We used a concentration–response function to relate outdoor air concentrations of PM10 to the selected health effect (Ostro et al., 1998; Loomis et al., 1999; Gouveia & fletcher, 2000; Conceicao et al., 2001; Saldiva & Bohm, 1995**).** A 10 µg/m^3 increase in ambient PM10 concentration results in a 1.66% (95% CI: 0.34–3.00) increase in daily respiratory disease mortality (less-conservatively, all-cause-mortality) for children 0–5 years of age (Ostro, 2004). When exposure is specified as a continuous variable (as is the case for PM10 concentration), the attributable fraction (AF) is calculated according to Equation 1.1:

$$AF = \frac{\int_{x=0}^{m} RR(x)P(x)dx - \int_{x=0}^{m} RR(x)P'(x)dx}{\int_{x=0}^{m} RR(x)P(x)dx} \qquad \text{Equation 1.1}$$

where:

x = exposure level;

P(x) = population distribution of exposure;

P'(x) = "counterfactual" population distribution of exposure;

RR(x) = relative risk at exposure level *x* compared to the reference level.

If it is not possible to express exposure on a continuous scale (i.e. a "scenario-based" approach is used), Equation 1 becomes:

$$AF = \frac{\sum P_i RR_i - \sum P_i' RR_i}{\sum P_i RR_i} \qquad \text{Equation 1.2}$$

where:

P_i = proportion of the population in exposure category *i*;

P_i' = proportion of the population in exposure category *i* after an intervention or other change ("counterfactual" exposure);

RR_i = relative risk at exposure category *i* compared to the reference level.

When there are only two groups (exposed and unexposed), the formula is further simplified:

$$AF = \frac{(P_1RR + P_0) - 1}{P_1RR + P_0} \qquad \text{Equation 1.3}$$

where:

P_1 = proportion of the population exposed;

P_0 = proportion of the population unexposed;

RR = relative risk.

For outdoor air pollution, we used Equation 1.1. In this case, RR is the relative risk of death for a given change in PM10 concentration. The change in PM10 concentration is the difference between the actual concentration observed in an area and a target value. Thus, the AF is the portion of the incidence rate (mortality rate, in this study) of a given outcome in a population that is due to a given exposure (Prüss-Üstün et al., 2003). To determine the number of deaths from exposure to high PM10 concentrations among children in the age group 0–4 years, the AF was applied to the baseline mortality rate in the age group, for each EUR subregion. The mortality rate for each subregion was obtained from 2001 Global Burden of Disease estimates of deaths (WHO, 2001). Some studies used death from all causes to estimate the dose–response relationship (Ostro et al., 1998; Loomis et al., 1999), while others used death from ARI (Gouveia & Fletcher, 2000; Conceicao et al., 2001; Saldiva & Bohm, 1995). These studies are summarized in Table 1.1. As the transferability of results from the countries where studies were performed to the EUR region depends upon various factors such as similarity in mortality structure or access and quality of health care, but the impact of air pollution to outcomes other than respiratory infections has been shown, we therefore performed the analysis twice, by applying the estimated relative risk to both outcomes. The expected number of deaths, E, was then estimated as: $E = AF \times B \times P$, where B is the baseline mortality (from all causes or from ARI), and P the exposed population.

Table 1.1 Child and infant mortality related to PM10 exposure

Source	City	Country	Age group (years)	PM measure	Diagnosis	Change per 10 unit increase (%)	95% CI
Conceição et al. (2001)	Sao Paulo	Brazil	0–4	PM10	All respiratory	1.61	-14.82, 21.22
Loomis et al. (1999)	Mexico City	Mexico	0–1	PM2.5[a]	All cause	6.87	2.48, 11.45
Saldiva & Bohm (1995)	Sao Paulo	Brazil	<5	PM10	All respiratory	-1.98	-6.54, 2.57
Gouveia & Fletcher (2000)	Sao Paulo	Brazil	<5	PM10	All respiratory	-0.09	-3.23, 3.14
Ostro et al. (1998)	Bangkok	Thailand	<6	PM10	All cause	1.80	0.23, 3.37
Overall			<5	PM10		1.66	0.34, 3.00

[a] Converted to PM10 assuming PM2.5 = 0.5 x PM10 (Ostro et al., 1998).

Each analysis was repeated using different PM10 threshold levels or "counterfactual exposures". A counterfactual exposure is an alternative exposure distribution that is used as the baseline to estimate the burden of disease caused by the exposure distribution of interest (Prüss-Üstün et al., 2003). The first threshold we used (10 µg/m^3) was a "background concentration" (i.e. the concentration that would exist with no man-made pollution). In this case, we calculated what can be considered the attributable mortality. Another threshold (20 µg/m^3) was the PM10 annual mean target set for the year 2010 by the European Union (EU) (Council of the European Union, 1999); in this case we calculated the avoidable mortality if this level were to be achieved. For EUR B and EUR C, analyses were also repeated using a PM10 threshold of 40 µg/m^3, which is the annual mean target set by the EU for the year 2005. This threshold of 40 µg/m^3 was not used for EUR A because the subregional weighted mean PM10 concentration is already lower than this level. Upper and lower estimates of the number of deaths attributable to outdoor air pollution were based on the range of the effect estimates (i.e. the upper and lower 95% confidence intervals around the relative risks).

This approach allowed the total number of premature deaths to be estimated. We did not estimate the number of DALYs due to outdoor air pollution, because there are not enough data to quantify the effect of short-term exposure on the disability rates or number of years lost. This follows the practice adopted by the global comparative risk assessment team.

1.3 Results

The burden of death attributable to outdoor air pollution, calculated by applying the relative risk to ARI mortality only, is given for the three EUR subregions in Tables

1.2–1.5. The corresponding burden, calculated by applying the increased risk to all-cause deaths, is given in Tables 1.6–1.9.

EUR A has the lowest average PM10 concentration of the three European subregions, according to World Bank and other estimates (see Table 1.2 footnotes *b* and *c* for a list of sources), and has the fewest deaths attributable to outdoor air pollution. Greater numbers of deaths among children 0–4 years of age occur in the other two subregions, particularly EUR B, even though their child populations are smaller than that of EUR A. The burden of disease attributable to outdoor air pollution is substantial in these two subregions, even if only the deaths associated with ARI are considered, instead of all-cause deaths.

In EUR A, the estimated mean PM10 concentration did not exceed the guideline of 40 $\mu g/m^3$ set by the European Community for the year 2005. If PM10 concentrations in EUR B and EUR C decreased to that level, and assuming that the current PM10 level is the lower of the two we used, we estimate that in EUR B annually 1026 ARI-associated deaths of children 0–4 years of age would have been prevented (3217 deaths if the relative risk is applied to all-cause mortality) (Tables 1.3 and 1.7). The corresponding figures for EUR C are 281 and 1788, respectively (Tables 1.4 and 1.8).

Starting from the same scenario, and applying the relative risk to ARI-associated deaths or all-deaths, a decrease of PM10 concentration to 20 $\mu g/m^3$ would have prevented the deaths of almost 2500 and 8000 children 0–4 years of age, respectively, in EUR B, and 250 and 3000 deaths, respectively, in EUR C. In EUR A, a decrease of PM10 outdoor air concentration to 20 $\mu g/m^3$ would result in a smaller number of preventable deaths among young children: 3–200 assuming a current PM10 level of 24.84 $\mu g/m^3$; and 11–600 assuming a current PM10 level of 36.55 $\mu g/m^3$, depending on whether ARI-associated deaths or all-cause deaths were used in the calculation. A further decrease of PM10 levels to 10 $\mu g/m^3$ would have resulted in an additional 700–2000 preventable deaths of young children in EUR B, 120–800 in EUR C, and 7–350 in EUR A, the high and low values again depending on whether ARI-associated deaths or all-cause deaths, respectively, were used in the calculation.

We also estimated the mortality burden for children 0–4 years of age in the EUR subregions, assuming that current PM10 concentrations in the three subregions correspond to the values calculated from the World Bank estimates (World Bank, 2003b), and setting 20 $\mu g/m^3$ as the PM10 target level. The results are summarized in Table 1.5 (applying the relative risk to ARI mortality) and in Table 1.9 (applying the relative risk to all-cause mortality).

Table 1.2 Deaths attributable to outdoor air pollution calculated by applying the relative risk to ARI[a] mortality, children 0–4 years of age, EUR A

Average PM10 (µg/m^3)	Target (µg/m^3)	Relative risk	Attributable fraction	Cases (*N*)	Lower estimate	Upper estimate
24.84[b]	10	1.02	0.024	10	2	19
24.84[b]	20	1.01	0.008	3	1	6
35.96[c]	10	1.04	0.042	18	4	32
35.96[c]	20	1.03	0.026	11	2	20

[a] Acute respiratory infection.

[b] Estimated from the World Bank (World Bank, 2003b).

[c] Estimated from epidemiological studies: Hoek et al., 1997; Pekkanen et al., 1997; Cerna et al., 1998; Brauer et al., 2000; Junker et al., 2000; Kingham et al., 2000; Kunzli et al., 2000; Larssen et al., 2000; van der Wal & Janssen, 2000; Biggeri, Bellini & Terracini, 2001; Howel, Darnell & Pless-Mulloli, 2001; Marcazzan et al., 2001; Querol et al., 2001; EEA, 2003; Naef & Xhillari, 2003; Peacock et al., 2003; Sokhi et al., 2003).

Table 1.3 Deaths attributable to outdoor air pollution calculated by applying the relative risk to ARI mortality, children 0–4 years of age, EUR B

Average PM10 (µg/m^3)	Target (µg/m^3)	Relative risk	Attributable fraction	Cases (*N*)	Lower estimate	Upper estimate
67.01[a]	10	1.10	0.090	4 074	866	7 092
67.01[a]	20	1.08	0.075	3 387	715	5 934
67.01[a]	40	1.05	0.044	1 978	412	3 512
53.86[b]	10	1.08	0.070	3 168	668	5 562
53.86[b]	20	1.06	0.055	2 466	516	4 358
53.86[b]	40	1.02	0.023	1 026	212	1 837

[a] Estimated from World Bank data (World Bank, 2003b).

[b] Estimated from epidemiological studies (see Table 1.2, footnote *c* for sources).

Table 1.4 Deaths attributable to outdoor air pollution calculated by applying the relative risk to ARI mortality, children 0–4 years of age, EUR C

Average PM10 (µg/m^3)	Target (µg/m^3)	Relative risk	Attributable fraction	Cases (*N*)	Lower estimate	Upper estimate
55.67[a]	10	1.08	0.073	598	126	1 048
55.67[a]	20	1.06	0.057	471	99	831
55.67[a]	40	1.03	0.026	210	44	376
61[b]	10	1.09	0.081	665	141	1 162
61[b]	20	1.07	0.066	539	113	948
61[b]	40	1.04	0.034	281	58	500

[a] Estimated from the World Bank (World Bank, 2003b).

[b] Estimated from epidemiological studies (see Table 1.2, footnote *c* for sources).

Table 1.5 Summary table of the burden of deaths attributable to outdoor air pollution in Europe calculated by applying the relative risk to ARI mortality, children 0–4 years of age[a]

Subregion	Deaths (*N*)	% of all-cause deaths	Deaths per 10 000 children
EUR A	3	<0.1	<0.1
EUR B	3 387	2.4	1.9
EUR C	471	0.9	0.4
Totals, EUR	3 861	1.8	0.7

[a] Assuming the current PM10 concentration is the level derived form World Bank country estimates (World Bank, 2003b), and that 20 μg/m³ is the target PM10 concentration.

Table 1.6 Deaths attributable to outdoor air pollution calculated by applying the relative risk to all-cause mortality, children 0–4 years of age, EUR A

Average PM10 (μg/m³)	Target (μg/m³)	Relative risk	Attributable fraction	Cases (*N*)	Lower estimate	Upper estimate
24.84[a]	10	1.02	0.024	541	112	969
24.84[a]	20	1.01	0.008	178	37	321
35.96[b]	10	1.04	0.042	938	195	1 667
35.96[b]	20	1.03	0.026	582	120	1 040

[a] Estimated from World Bank data (World Bank, 2003b).

[b] Estimated from epidemiological studies (see Table 1.2, footnote *c* for sources).

Table 1.7 Deaths attributable to outdoor air pollution calculated by applying the relative risk to all-cause mortality, children 0–4 years of age, EUR B

Average PM10 (μg/m³)	Target (μg/m³)	Relative risk	Attributable fraction	Cases (*N*)	Lower estimate	Upper estimate
67.01[1]	10	1.10	0.090	12 770	2 715	22 232
67.01[1]	20	1.08	0.075	10 617	2 242	18 602
67.01[1]	40	1.05	0.044	6 201	1 293	11 008
53.86[2]	10	1.08	0.070	9 931	2 093	17 436
53.86[2]	20	1.06	0.055	7 730	1 619	13 660
53.86[2]	40	1.02	0.023	3 217	665	5 760

[a] Estimated from World Bank data (World Bank, 2003b).

[b] Estimated from epidemiological studies (see Table 1.2, footnote *c* for sources).

Table 1.8 Deaths attributable to outdoor air pollution calculated by applying the relative risk to all-cause mortality, children 0–4 years of age, EUR C

Average PM10 (µg/m^3)	Target (µg/m^3)	Relative risk	Attributable fraction	Cases (*N*)	Lower estimate	Upper estimate
55.67[a]	10	1.08	0.073	3 811	804	6 684
55.67[a]	20	1.06	0.057	3 001	629	5 298
55.67[a]	40	1.03	0.026	1 340	277	2 397
61[b]	10	1.09	0.081	4 237	897	7 406
61[b]	20	1.07	0.066	3 435	723	6 042
61[b]	40	1.04	0.034	1 788	371	3 187

[a] Estimated from World Bank data (World Bank, 2003b).

[b] Estimated from epidemiological studies (see Table 1.2, footnote *c* for sources).

Table 1.9 Summary table of the burden of deaths attributable to outdoor air pollution calculated by applying the relative risk to all-cause mortality, European children 0–4 years of age[a]

Subregion	Deaths	% of all-cause deaths	Deaths per 10 000 children
EUR A	178	0.8	0.1
EUR B	10 617	7.5	5.9
EUR C	3 001	5.8	2.6
Total EUR	13 796	6.4	2.7

[a] Assuming that the current PM10 concentration is the level derived form World Bank country estimates (World Bank, 2003b), and that 20 µg/m^3 is the target PM10 concentration.

1.4 Discussion

The results indicate that a significant burden of mortality in children is attributable to outdoor air pollution This is particularly true in countries of the EUR B and EUR C subregions, where outdoor air pollution is estimated to be responsible for 2.4% and 0.9%, respectively, of all-cause deaths (applying relative risk to ARI mortality only), and 7.5% and 5.8%, respectively, (if the relative risk is applied to all-cause mortality), among children 0–4 years of age. These results are important because they quantify the impact of outdoor air pollution on child mortality. However, they should be considered in light of a number of methodological issues.

First, PM10 was used as a proxy for outdoor air pollution, but other co-pollutants not related spatially or temporally with PM10 may impact child health and affect the data. Also, we estimated only a subset of adverse outcomes (i.e. fatal outcomes), therefore the burden of disease attributable to outdoor air pollution was underestimated. For example, the impact on upper respiratory illnesses, or on entirely different outcomes (e.g. low birth weight and long-term health effects), were not considered.

Although two sets of data were used for the analysis (see Table 1.2 footnotes *b* and *c* for sources), subregional PM10 levels from either data set may be biased. World Bank PM10 estimates were calculated for each country from a regression model and may not necessarily reflect true country PM10 levels. The lack of suitable epidemiological studies for some countries means that some subregional PM10 estimates were calculated on the basis of few fixed-site measurements. Of all the studies conducted in EUR C countries, only one reported PM10 measurements (for Hungary; Hoek et al., 1997); all the others measured outdoor air pollution in terms of dust, black smoke, or total suspended particulates (Larson et al., 1999; CEROI, 2003; Ecological Monitoring Centre, 2003). It should be noted that our estimates are based on Regional averages, assuming equal exposures across countries. Subregional results, however, may not apply to all member countries. In EUR A, for example, the subregional mean PM10 concentration was below 40 $\mu g/m^3$ and consequently we assumed there would be no beneficial effects from reducing the PM10 concentration to that value in the subregion, even if there are cities in EUR A where the PM10 concentrations are higher and a decrease to 40 $\mu g/m^3$ could result in substantial health gains.

The intervals around the burden of disease estimates are wide, as a consequence of the variability in the relationship between PM10 and the health outcomes estimated by different studies (Ostro et al., 1998; Loomis et al., 1999; Gouveia & Fletcher, 2000; Conceicao et al., 2001; Saldiva & Bohm, 1995). Errors may also be introduced when relative risk estimates from studies in other countries (Mexico, Thailand, Brazil) are extrapolated to the European Region, depending on differences in the incidence of respiratory infections, mortality, coding of cause of death diagnosis, socioeconomic factors, and accessibility to and quality of health-care services. In addition, the studies were not homogeneous with respect to the outcome studied. For this reason, we decided to apply the relative risk estimate to deaths due to ARI only, as well as to all-cause deaths. Applying the relative risk to all-cause deaths probably overestimates the burden of disease in Europe, whereas applying the relative risk only to ARI deaths may underestimate the burden of disease, since outdoor air pollution has been linked to other causes of death (Perera et al., 1998; Dejmek et al., 2000; Rogers et al., 2000). In the summary results of this guide we present both estimates, considering the former as an upper boundary and the latter as a lower boundary of the burden of deaths from outdoor air pollution in Europe.

1.5 Conclusions

EUR B and EUR C carry the largest proportion of the burden of disease due to outdoor air pollution in children 0–4 years of age. The AF for preventable deaths was estimated to be 2.4–7.5% in EUR B, and 0.9–5.8% in EUR C, depending on the method of estimation used. The attributable burden was calculated as the number of deaths that could be avoided if the target PM10 concentration of 20 $\mu g/m^3$ were met, because this level seemed to be a realistic target for all countries in the European Region (Tables 1.5 and 1.9). However, if we consider that all deaths due to PM10 concentrations exceeding the theoretical background concentration of 10 $\mu g/m^3$ should be attributed to outdoor air pollution, then the values in the tables are a conservative estimate of the actual mortality attributable to air pollution. A cost–effectiveness analysis of the number of preventable deaths would provide further evidence of the benefits of reducing outdoor air pollution.

2. Indoor air pollution (solid fuel use)

2.1 Introduction

Indoor sources of air pollution may be associated with a substantial burden of disease in childhood because they are likely to produce very high exposure levels (Ezzati & Kammen, 2001). Since children spend a great deal of their time indoors, they are likely to reach high levels of exposure even to pollutants at relatively low air concentrations, and exposure levels can be even higher under conditions of poor ventilation. On a global basis, solid fuel use (SFU) represents the largest source of indoor air pollution. Household combustion of coal or biomass for cooking and heating produces smoke that contains carbon monoxide, nitrogen oxides, sulphur oxides, benzene, formaldehyde, polyaromatic compounds, and suspended particulates (WHO, 1999).

Several diseases have been linked to the exposure to SFU, including acute lower respiratory infections (ALRI) in young children and asthma in school-aged children (Bruce et al., 2000; Ezzati & Kammen, 2001). The evidence for the association between indoor air pollution and ALRI in small children is strong: several studies suggest that indoor air pollution increases the risk, although there is variability in the relative risk estimates (Bruce, Perez-Padilla & Albalak, 2002). The evidence for the association between exposure to solid fuels and asthma is moderate (see Annex 2), with a number of studies finding no effect, and others suggesting that indoor air pollution may increase the risk (Bruce, Perez-Padilla & Albalak, 2002).

In this section, we provide estimates of the burden of selected diseases that is attributable to indoor smoke from household SFU, for children 0−14 years old.

2.2 Methods

We estimated the burden of disease for outcomes and age groups for which there is strong evidence of an association (Annex 2). For this reason, ALRI was the outcome analysed in the age group 0–4 years, whereas asthma was investigated in the age group 5−14 years. Asthma was not considered to be an outcome for children 0–4 years old because there are no reliable estimates of the association between exposure to SFU and disease for this age group. For the same reason, we did not calculate a burden of disease (ALRI and asthma) attributable to indoor air pollution for people 15−19 years of age.

We used estimates of child exposure to SFU reported by Smith, Mehta & Feuz (2003). Exposure to solid fuels in the population was estimated as the product of the proportion of households using solid fuels, and a ventilation factor that reflected both ventilation and stove characteristics. The exposure of children (0−14 years of age) to indoor smoke from solid fuels in the three European subregions is given in Table 2.1. See Annex 3 for a list of countries for which estimates of household SFU were available.

Table 2.1 Exposure of children (0–14 years old) to indoor smoke from solid fuels, European subregions[a]

Subregion	Household SFU[b] (%)	Ventilation factor	Adjusted prevalence of exposure (%)	95% CI (%)
EUR A	0.2	0.73	0.0	0.0–0.4
EUR B	41.5	0.51	20.5	16.2–24.5
EUR C	22.8	0.24	6.4	4.3–10.4

[a] Source: (Smith, Mehta & Feuz, 2003).

[b] Abbreviations: SFU = solid fuel use. CI = confidence interval.

The relative risk for the association between exposure to indoor smoke from SFU and ALRI in children 0–4 years of age was estimated to be 2.3 (95% CI: 1.9–2.7; Smith, Mehta & Feuz, 2003). For asthma in children 5−14 years of age, the approach for estimating the relative risks and confidence intervals was different because the association was moderate. In this case, the lower end of the relative risk was set at 1.0 (no effect) and the upper end at the geometric mean of the available relative risks from studies of households in developing countries. The central estimate was set at the geometric mean between the upper and lower ends of the nominal confidence interval. Using this approach, a relative risk of 1.6 (95% CI: 1.0–2.5) was estimated (Desai, Mehta & Smith, 2003).

The attributable fraction (AF) for the whole population was calculated as described in the Section 1, *Outdoor air pollution*, using the formula for only two exposure levels (Equation 1.3). The attributable burden (AB) was then calculated as:

$$AB = AF \times \text{disease burden}$$

The burdens for ALRI and asthma were obtained from Global Burden of Disease 2001 estimates (WHO, 2001). Uncertainty in the final burden of disease estimates attributable to indoor air pollution was expressed as the lower and upper estimates of the 95% CI values for the relative risks. For the outcomes included in the analysis, the width of the interval between lower and upper estimates expresses the uncertainty in the relative risk estimates, but not the exposure.

2.3 Results

2.3.1 The burden of ALRI for children 0–4 years of age (strong evidence, see Annex 2)

It has been estimated that, in 2001, 385 children 0–4 years of age died from ALRI in EUR A; 44 145 died in EUR B; and 7 234 died in EUR C (WHO, 2001). The morbidity burden of ALRI in the three subregions was estimated to be 14 630 DALYs, 1 527 799 DALYs and 251 724 DALYs, respectively. The corresponding burden of ALRI attributable to SFU is shown for the three EUR subregions in Tables 2.2–2.4. In EUR A, where virtually all households use cleaner cooking and heating systems, there was no attributable burden for ALRI due to indoor air pollution (Table

2.2). Proportionally, the greatest burden from ALRI attributable to household SFU was in EUR B (Table 2.3). In this subregion, over 9 000 deaths and 320 000 DALYs could be prevented every year if children were no longer exposed to indoor smoke from SFU. The burden of ALRI that is attributable to household SFU in the three EUR subregions is summarized in Table 2.5 for children 0–4 years of age.

2.3.2 The burden of asthma for children 5–14 years of age (moderate II evidence, see Annex 2)

It has been estimated that, in 2001, asthma caused 53 deaths and 191 656 DALYs among children 5–14 years of age in EUR A; 69 deaths and 92 795 DALYs in EUR B; and 27 deaths and 44 186 DALYs in EUR C (WHO, 2001). The corresponding burdens from asthma attributable to SFU are given in Tables 2.6–2.8. In EUR A, the burden of asthma attributable to SFU was zero (Table 2.6), while children in EUR B bore the heaviest burden (Table 2.7).

Table 2.2 Acute lower respiratory infections in children 0–4 years of age attributable to household use of solid fuels, EUR A, year 2001

	Burden of disease attributable to SFU Central estimate (lower–upper)	% of total ALRI burden Central estimate (lower–upper)	ALRI per 10 000 children Central estimate (lower–upper)
Deaths	0 (0–0)	0 (0–0)	0 (0–0)
DALYs	0 (0–0)	0 (0–0)	0 (0–0)

Table 2.3 Acute lower respiratory infections in children 0–4 years of age attributable to household use of solid fuels, EUR B, year 2001

	Burden of disease attributable to SFU Central estimate (lower–upper)	% of total ALRI burden Central estimate (lower–upper)	ALRI per 10 000 children Central estimate (lower–upper)
Deaths	9 289 (6 876–11 409)	21.0 (15.6–25.8)	5.1 (3.8–6.3)
DALYs	321 483 (237 973–394 837)	21.0 (15.6–25.8)	177.7 (131.6–218.3)

Table 2.4 Acute lower respiratory infections in children 0–4 years of age attributable to household use of solid fuels, EUR C, year 2001

	Burden of disease attributable to SFU Central estimate (lower–upper)	% of total ALRI burden Central estimate (lower–upper)	ALRI per 10 000 children Central estimate (lower–upper)
Deaths	556 (394–710)	7.7 (5.4–9.8)	0.3 (0.4–0.6)
DALYs	19 335 (13 710–24 700)	7.7 (5.4–9.8)	15.4 (10.9–19.7)

Table 2.5 Summary of the burden of ALRI in children 0–4 years of age attributable to household solid fuel use in EUR, year 2001

	Deaths			DALYs		
Subregion	**Deaths**	**% of all-cause deaths**	**Deaths per 10 000 children**	**DALYs**	**% of all-cause DALYs**	**DALYs per 10 000 children**
EUR A	0	0	0	0	0	0
EUR B	9 289	6.6	5.2	321 483	5.0	178.9
EUR C	556	1.1	0.5	19 335	0.7	17.0
Total EUR	9 845	4.6	1.9	340 818	3.1	66.1

Table 2.6 Asthma in children 5–14 years of age attributable to household use of solid fuels, EUR A, year 2001

	Burden of disease attributable to SFU Central estimate (lower–upper)	**% of total asthma burden Central estimate (lower–upper)**	**Asthma per 10 000 children Central estimate (lower–upper)**
Deaths	0 (0–0)	0 (0–0)	0 (0–0)
DALYs	0 (0–0)	0 (0–0)	0 (0–0)

Table 2.7 Asthma in children 5–14 years of age attributable to household use of solid fuels, EUR B, year 2001

	Burden of disease attributable to SFU Central estimate (lower–upper)	**% of total asthma burden Central estimate (lower–upper)**	**Asthma per 10 000 children Central estimate (lower–upper)**
Deaths	8 (0–16)	11.5 (0–23.5)	<0.1 (0– <0.1)
DALYs	10 164 (0–21 824)	11.5 (0–23.5)	2.6 (0–5.7)

Table 2.8 Asthma in children 5–14 years of age attributable to household use of solid fuels, EUR C, year 2001

	Burden of disease attributable to SFU Central estimate (lower–upper)	**% of total asthma burden Central estimate (lower–upper)**	**Asthma per 10 000 children Central estimate (lower–upper)**
Deaths	1 (0–2)	3.7 (0–8.8)	<0.1 (0–<0.1)
DALYs	1 634 (0–3 870)	3.7 (0–8.8)	0.5 (0–1.1)

2.4 Discussion

The results indicate that household SFU does not cause a substantial burden of ALRI among young children living in EUR A, where such fuel use, and hence exposure, is rare. In contrast, domestic combustion of solid fuels is still common in EUR B and EUR C (e.g. it is estimated that approximately two fifths of households in EUR B use solid fuels) (Smith, Mehta & Feuz, 2003). To some degree, the effects of SFU in these two subregions have been mitigated because a history of household SFU has led to the development of efficient techniques for lowering or eliminating indoor air emissions. Despite this, indoor air pollution from SFU causes significant ALRI mortality and morbidity among young children in these two subregions. In EUR B alone, it is estimated that almost 10 000 children 0–4 years of age died from ALRI attributable to household SFU in the year 2001. This is more than one fifth of all-cause deaths in the age group. Clearly, it would be greatly beneficial for the children if households in EUR B and EUR C countries could climb the "energy ladder" and shift from solid fuels to cleaner liquid or gaseous fuels.

The burden of disease estimates presented here are subject to some limitations, especially that concerning the assessment of exposure to indoor air pollution. To date, there are few studies assessing household use of solid fuels, therefore a statistical model had to be developed to predict national SFU from a number of country-specific development parameters (Smith, Mehta & Feuz, 2003). This points out the need to collect better data from national surveys, such as those proposed by WHO in the World Health Survey initiative (WHO, 2004). In addition, burden of disease analyses consider exposure to solid fuels to be a binary variable (exposed or not exposed). This is consistent with the epidemiological literature (Smith, Mehta & Feuz, 2003), but in reality many different levels of exposure to indoor air pollution may occur, depending on the type and quality of the fuel and stove, cooking and heating methods, activity patterns, and the season.

The present work does not consider indoor pollutants (e.g. environmental tobacco smoke) other than smoke generated by SFU. Considering the important effects of environmental tobacco smoke on perinatal and child health (Courage, 2002), the actual burden of disease attributable to indoor air pollution is probably greater than that estimated here. Other diseases believed to be associated with SFU are also not included in the burden of disease analysis because the evidence on causality is either indirect or insufficient. Perinatal conditions are probably the most important of such excluded effects.

Asthma is included as an outcome for children 5−14 years of age, although the evidence on the cause–effect relationship is only moderate. Therefore, the results regarding this outcome should be interpreted conservatively.

2.5 Conclusions

Children 0–4 years old in countries of the EUR B and EUR C subregions bear all of the burden of disease from ALRI that is attributable to indoor air pollution. Economic growth and modernization are the factors most likely to contribute to a reduction in the use of solid fuels in the home and lead to a significant improvement in the health of children.

3. Water, sanitation and hygiene

3.1 Introduction

One sixth of the world's population, approximately 1.1 billion people, do not have access to safe water and 2.4 billion lack basic sanitation. Six thousand children die every day from diarrhoeal diseases alone and a large proportion of diarrhoeal disease in the developing world is due to poor water, sanitation and hygiene (UNICEF, 2003). In Europe, the health effects of poor water, sanitation and hygiene have been underemphasized because it is assumed that industrialized nations do not have problems in this area. Indeed, it is estimated that over 90% of the population of Europe is covered by an improved water supply (Duke et al., 1996; Hildebrand et al., 1996; Merrick, Davidson & Fox, 1996). However, outbreaks of water-related disease occur even in these areas, due to temporary breaks in microbiological water quality, or to the use of intermittent, small water supplies (Duke et al., 1996; Hildebrand et al., 1996; Merrick, Davidson & Fox, 1996). In many of the new countries of Europe, such as those of the former Soviet Union, the water and sanitation infrastructure is underdeveloped, or has been disrupted due to lack of maintenance during the last two decades. The water, sanitation and hygiene situation may thus not be very different from that found in the developing world. Therefore, a true estimate of the burden of disease in these countries is warranted.

In this section, we estimate the burden of diarrhoeal disease in children in the European subregions that is due to unsafe water, sanitation and hygiene. It is one of the first such estimates to be based on a combination of exposure and evidence-based risk assessment.

3.2 Methods

We estimated the burden of diarrhoeal disease in children due to poor water, sanitation and hygiene, using two age groups: 0–4 years and 5–14 years. We used United Nations year 2000 population estimates (2002 revision) in the calculations (UNPD, 2002). The European Member States included in the analyses were classified according to the WHO subregions, based on levels of child and adult mortality (see Annex 1).

Exposure analysis formed the basis of our estimates for the burden of disease due to water sanitation and hygiene. Exposure at the household or individual level was based on an approach developed at WHO (Prüss et al., 2002). This “scenario based” approach assumes typical exposure scenarios of a population, based on combinations of risk factors and policy. Levels of faecal—oral pathogen loads in the environment characterize the major differences between the scenarios (Prüss et al., 2002). For example, of the six exposure scenarios, scenario I represents the ideal situation where there is no transmission of diarrhoeal disease through poor water, sanitation and hygiene. Successively higher levels represent an increasing risk of transmission of diarrhoeal disease. A breakdown of these scenarios is found in Annex 4. The relative risk of developing diarrhoeal disease for each of these scenarios was calculated using information from the literature (Prüss et al., 2002). Quantification of risk in the transitions between scenarios IV−VI was also supported by studies in the literature. However, the transition between scenarios II and IV remained the most uncertain, because there were few data for estimating risk. The transition corresponds to that between environments with low and high pathogen loads that are typical in developed and developing countries, respectively. Consequently, the estimates made for this transition were based on studies of particular aspects of these environments. For example, studies on the transition from scenario IV to IIIa (improvement in drinking-water quality) estimated that the of risk reduction due to point-of-use disinfection varied between 44.7–54.5%. In calculating the disease burden, a lower, best and upper risk estimate was thus calculated, based on risk estimates from specific interventions. The lower estimate represents the benefit in risk achieved by improvements in personal hygiene only (e.g. safe drinking-water storage and disinfection in the home), whereas the best or most "realistic" estimate represents improvements in personal hygiene and in water-supply quality (Prüss et al., 2002). The upper estimate in risk would be achieved if there was the addition of a continuous piped water supply. These ranges of risk estimates formed the basis of the sensitivity analysis in our study. The population of each European subregion was distributed into exposure categories (Annex 4), based on information from the Global Water Supply and Sanitation Assessment 2000 (WHO, 2000b).

To calculate the AF of diarrhoeal disease due to poor water, sanitation and hygiene, we used Equation 1.2 (Section 1, *Outdoor air pollution*). We associated the relative risk in each of the scenarios with the proportion of the population in each of the exposure categories, and calculated estimates of the disease burden and mortality (based on an estimate of the proportion of total diarrhoea disease).

The AF was then applied to the 2001 burden of disease estimates for children, to give estimates of deaths and DALYs due to poor water sanitation and hygiene. We also estimated how changing exposure scenarios in EUR B and EUR C could impact the burden of disease in those subregions. For each subregion, we created two hypothetical settings, A and B. Setting A was formed by placing half of the population into scenario IV and half into II (Annex 4). Setting B was formed by placing the total population into scenario II (Annex 4).

3.3 Results

The distributions of the child populations of EUR A, EUR B, and EUR C into exposure scenarios are given in Table 3.1.

Table 3.1 Distribution of population by exposure scenario, EUR subregions

EUR A	EUR B	EUR C
100% in II	12% in VI 1% in Vb 8% in Va 79% in IV	1% in VI 5% in Va 94% in IV

Based on the estimated exposure scenarios, the AF of diarrhoeal disease due to poor water, sanitation and hygiene is 60%, 87% and 86% in EUR A, EUR B and EUR C, respectively. Table 3.2 shows the AFs, deaths and DALYs, with uncertainty intervals based on levels of relative risk.

Table 3.2 Estimates of attributable diarrhoea deaths and DALYs in children 0–14 years of age caused by poor water, sanitation and hygiene in 2001.

	Subregion		
	EUR A[a]	**EUR B**	**EUR C**
Attributable fraction			
Lower Estimate	60%	76%	74%
Best Estimate	60%	87%	86%
Upper Estimate	60%	94%	94%
Deaths			
Lower Estimate	63	10 374	1 385
Best Estimate	63	11 876	1 609
Upper Estimate	63	12 831	1 759
DALYs			
Lower Estimate	25 946	390 276	66 455
Best Estimate	25 946	446 763	77 231
Upper Estimate	25 946	482 710	84 416

[a] In EUR A, 100% of the population is in scenario II, and the lower and upper estimates of the relative risk are therefore the same.

Table 3.3 shows the consequences of changing the population distribution in the exposure scenarios. In EUR B, moving half of the child population into scenario IV and half into scenario II would save approximately 1000 lives and 40 000 DALYs, whereas moving all the child population into scenario II (the same as in EUR A), would save approximately 3700 lives and 140 000 DALYs. In EUR C, moving half of the children into scenario IV and half into scenario II would prevent approximately 130 deaths and 6000 DALYs, whereas moving all the children into scenario II would prevent approximately 500 deaths and 17 000 DALYs. It should be noted that these are conservative estimates, as the method applied here estimates only expected changes in the *proportion* of the total diarrhoea burden that is attributable to poor water and sanitation. In reality, large-scale improvements in water supplies are also likely to cause reductions in the overall *amount* of diarrhoea burden.

Table 3.3 Estimates of attributable diarrhoea deaths and DALYs in children 0–14 years of age for different scenarios, EUR B and EUR C.

Scenario	EUR B
Attributable Fraction	
Current scenario (12% in VI, 1% in Vb, 8% in Va, 79% in IV)	87%
Setting A (50% in IV, 50% in II)	79%
Setting B (100% in II)	60%
Deaths	
Current scenario (12% in VI, 1% in Vb, 8% in Va, 79% in IV)	11 876
Setting A (50% in IV, 50% in II)	10 784
Setting B (100% in II)	8 190
DALYs	
Current scenario (12% in VI, 1% in Vb, 8% in Va, 79% in IV)	446 763
Setting A (50% in IV, 50% in II)	405 682
Setting B (100% in II)	308 113

Scenario	EUR C
Attributable Fraction	
Current scenario (1% in VI, 5% in Va, 94% in IV)	86%
Setting A (50% in IV, 50% in II)	79%
Setting B (100% in II)	60%
Deaths	
Current scenario (1% in VI, 5% in Va, 94% in IV)	1 609
Setting A (50% in IV, 50% in II)	1 478
Setting B (100% in II)	1 123
DALYs	
Current scenario (1% in VI, 5% in Va, 94% in IV)	77 231
Setting A (50% in IV, 50% in II)	70 945
Setting B (100% in II)	53 882

Table 3.4 summarizes the estimates for deaths and DALYs as a percentage of all-cause deaths and DALYs. The burden of disease of diarrhoeal disease due to poor water, sanitation and hygiene is estimated to be 5.3% of all deaths and 3.5% of all DALYs in Europe.

Table 3.4 Estimates of the burden of diarrhoeal disease in European children 0–14 years of age attributable to poor water, sanitation and hygiene, 2001

Subregion	Deaths	% all-cause deaths	Deaths per 10 000 children	DALYs	% all-cause DALYs	DALYs per 10 000 children
EUR A	63	0.2	0.01	25 946	0.8	3.71
EUR B	11 876	7.5	2.01	446 763	5.2	75.75
EUR C	1 609	2.4	0.36	77 231	1.6	17.04
Total Europe	13 548	5.3	0.77	549 940	3.5	31.53

3.4 Discussion

The results of the exposure-based burden of disease estimates from this study are consistent with reports that poor water, sanitation and hygiene is a major source of morbidity and mortality in children (Black, Morris & Bryce, 2003), and that this is most notable in EUR B. In interpreting the results of this analysis, however, it is important to note that there are many uncertainties in the sources of data. Incidence reporting of diarrhoeal cases can vary greatly from country to country. Only a fraction of diarrhoeal disease that occurs is actually recorded by the health sector and therefore underreporting is a common problem. This is compounded by the fact that each country has varying levels of sophistication in detection, investigation and reporting of diarrhoeal disease. Less-developed countries are likely to have inconsistent reporting, or lack health services or access to these services.

There were also some uncertainties in water sanitation and hygiene coverage. Estimates of coverage data from the Global Water Supply and Sanitation 2000 report were based on the results of a population survey. Even though a substantial portion (96%) of the European Regional population surveyed had access to improved water supply, the data were collected from only 44% of the population and consequently portions of the population may have been underrepresented (WHO, 2000b). In addition, water coverage may not reflect actual use, especially in rural areas where water is often not monitored and/or comes from various private and public sources. Finally, coverage does not necessarily mean facilities are operational or monitored for quality of treatment and therefore the quality of the water supply may not be reflected in the coverage estimates.

The exposure–risk estimates used in this analysis are also subject to some uncertainty since the relative risk associated with some scenarios is less well documented in the literature. To account for it, upper and lower estimates of disease burden were included in our results.

3.5 Conclusions

Overall, our estimates of AFs due to poor water, sanitation and hygiene are similar to those reported in the *World Health Report 2002* (WHO, 2002). The burden of disease is estimated to be 5.3% of all deaths and 3.5% of all DALYs in children 0–14 years of age in the European Region. The largest contribution to the burden of disease comes from EUR B, with over 11 000 deaths and almost 500 000 DALYs. Our results also point out the number of deaths and DALYs that could be avoided by simple interventions in personal hygiene. Additional research at regional or national levels using similar methods would be an important input into national water and sanitation policy and planning decisions.

4. Lead

4.1 Introduction

Many health effects are associated with lead. At high (>60 µg/dl) blood lead levels (BLL) acute effects can range from gastrointestinal symptoms, lethargy and irritability, to encephalopathy and death. At lower BLL, lead can produce chronic toxicity, which can remain asymptomatic. Infants and young children are most susceptible to chronic lead toxicity due to the unique vulnerability of the developing brain, and BLL as low as 10 µg/dl or less can cause significant neurological deficit (Needleman & Gatsonis, 1990; Canfield et al., 2003). For example, it is generally agreed that there is an inverse relationship between IQ and BLL (Lidsky & Schneider, 2003). Although the loss of a few IQ points at the individual level cannot be characterized as a disease, on a population basis the loss may have a large public-health impact, since it increases the incidence of mild mental retardation (MMR) (Landrigan et al., 2002).

Lead can be found in a variety of places in the environment, including air, dust, soil and water. It is deposited there by industrial emissions, gasoline, paint, plumbing, and cultural and food practices, and enters the body through inhalation and ingestion. As the health effects of lead have become more apparent, many countries have instituted regulations that control lead emissions from industry, and lead in paint, gasoline and plumbing. Despite the known health effects of lead and its presence in the environment, few countries conduct routine environmental monitoring for lead. More commonly, measurements of the body burden of lead is based on samples of blood, hair and teeth. The most common form of biomonitoring is to measure BLL, but countries often conduct episodic studies, as opposed to routine monitoring (UNEP, 1998). Most biomonitoring studies of BLL however, are done on populations at risk (e.g. industrial workers), or living in areas with high lead contamination in the environment. Since children are more susceptible to the neurotoxic effects of lead, and may also be particularly exposed because of behaviour (e.g. hand-to-mouth behaviour), studies in children are particularly important.

In 2001, the global disease burden from lead-induced disease was estimated to be 0.4% of all deaths and 0.9% of DALYs (WHO, 2002). To estimate the burden of disease attributable to lead in the child population, we combined exposure data from studies on children in the European Region with data on health effects. The method is illustrated by an analysis of the attributable disease burden of lead-induced MMR in children 0–4 years old, for 2001 in the European Region.

4.2 Methods

We estimated the burden of disease for children in the age group 0–4 years that could be attributed to elevated lead levels. Even though loss of IQ points is associated with cognitive deficits (Needleman & Gatsonis, 1990), their effects on functioning at low BLL ($\leq$5 µg/dl) may not always be clinically evident. Therefore, we considered only the incidence of MMR as the outcome. MMR occurs when the IQ is below 70 points, but above 50 points. We used the United Nations year 2000 population estimates (2002 revision) in our calculations (UNPD, 2002). The European Member States included in the analyses were classified according to the WHO subregions of child and adult mortality (see Annex 1).

The burden of disease calculation for lead is based on exposure assessments (measured as BLL) and the established associations with health effects such as MMR (Fewtrell, Kaufmann & Prüss-Üstün, 2003). Sources of information for BLL included national institutes and environmental research bodies, advocacy organizations and universities. We conducted an exhaustive country-specific MEDLINE and internet search for English, French or Spanish language studies that measured BLL in children. The search was limited to WHO Member States, and used the keywords “lead poisoning”, “country”, and “children”. We located further sources by cross-referencing and by using links to related articles. Data required for the assessment were: year of study; mean lead level (preferably geometric mean); sample size; standard deviation; market share of unleaded gasoline (as a surrogate for the presence or absence of lead-prevention activity). Studies were included in the database if they satisfied the following criteria:

- The study was performed within seven years of the 2001 burden of disease assessment. The latest study available was included if no other country data were available.
- The mean BLL was reported.
- The BLL was based on venous blood sampling. Data from capillary samples were used if a quality assessment was included in the methods, together with an interlaboratory confirmation.
- Samples were not taken from children living near lead/metal mining/smelting, or near contaminated environments.

Methods for sampling, measuring and reporting varied between studies. Since only limited information was available in certain Member States, we also included studies if they did not specify the type of mean, reported only arithmetic means, or did not report standard deviations. However, we attempted to include only studies of high quality, including those that controlled for possible contamination of the blood samples, and that used a representative population. Of 64 studies screened from the literature and national statistics, 24 were used in the final analysis, 14 from EUR A[1], 7 from EUR B[2] and 3 from EUR C[3].

There is a well-established correlation between lead in gasoline and lead in air, but whether this correlation could be extended to BLL had been uncertain. However,

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[1] Menditto et al., 1990; Maravelias et al., 1994; Flurin et al., 1998; O’Donohoe et al., 1998; Ponka, 1998; Sole, Ballabriga & Dominguez, 1998; Benes et al., 2000; Berglund et al., 2000; Leroyer et al., 2000; Prpic-Majic et al., 2000; Henriques & Calheiros, 2001; Zimova et al., 2001; Wilhelm et al., 2002; Mayan, Garcia-Algar et al., 2003).

[2] Zeida et al., 1995; Sarayan, 1996; Factor-Litvak et al., 1999; Furman & Laleli, 1999; Osman et al., 1999; Fischer et al., 2002; Bainova, **1995**).

[3] Bitto, Horvath & Sarkany, 1997; Hassanien & Horvath, 1999; Rubin et al., 2002).

recent studies have demonstrated that average BLL in a population clearly trend lower after leaded gasoline is phased out (UNEP, 1998; Thomas et al., 1999). Consequently, BLL measured prior to the introduction of lead prevention programmes, or to leaded gasoline phase-out, may not reflect current BLL. Therefore, a reduction factor was applied to mean BLL in the population if a lead prevention programme was in effect at the time of the study. The reduction factor was based on studies that showed BLL decreased from 30% to 48% over a five-year period (Fewtrell, Kaufmann & Prüss-Üstün, 2003). A midpoint of 39% over five years (7.8% per year) was used to calculate a reduction in BLL from the date of the sampling to the date of the current estimates (i.e. 2001). We used data from the World Bank (Lovei, 1998), Michael Walsh (Walsh, 2003), and the Fourth and Fifth Ministerial Conferences on the Environment for Europe (UNECE, 2000, 2003) to determine the status of leaded gasoline phase-out in Member States. The most recent data in the reports on lead phase-out status and market-share activity are from 1996. A country was considered to have a lead prevention programme if, at the time of the study, they reported at least a 50% market share of unleaded gasoline.

4.2.1 Estimating the disease burden

BLL for the child population were obtained from the literature for each country in the European Region. To calculate the disease burden of lead in this population for the year 2001, we adjusted the data from the literature downward to account for the effects of lead reduction programmes. The adjusted country BLL for 2001 were weighted first by sample size (for countries with more than one study), and then by the size of the child population in the 0–4 years age group, and pooled to form an aggregate mean at the subregional level. The proportions of the population in different BLL intervals were then calculated and superimposed on the health effects, which yielded the incidences of the health effects. The incidence was then used to calculate burden of disease estimates in terms of YLL, YLD and DALYs. A detailed description of the method is given in the following paragraphs.

4.2.2 Adjustment factors

Two adjustment factors were used in the calculations. The first, described above, was a *reduction factor* to account for lead prevention activity, and was used in the calculations of the subregional mean BLL. The second factor, a *regional adjustment ratio,* was used to account for regional variation in the prevalence of diseases that result in mental retardation. This variation leads to differences in the proportions of the population in given IQ intervals (Fewtrell, Kaufmann & Prüss-Üstün, 2003). The factor is used in the calculation of the MMR incidence.

After screening the studies for quality, applicability and representativeness of the population, we separated the countries into categories based on the presence or absence of lead phase-out activity (out-phased and non out-phased). Studies reporting urban and rural sample means were combined. For countries with lead-prevention programmes at the time of the study, we applied a reduction factor for each year a lead prevention programme was in place.

4.2.3 Country mean values

For countries with more than one study, a single, sample-size weighted mean BLL was generated by first multiplying the sample sizes by the natural logarithm of the mean BLL for the different studies. The weighted mean value for the country was then obtained by taking the antilogarithm of the average of the resulting values. The reduction factor (0.078 per year) was applied at this step if a lead-prevention programme was in place.

4.2.4 Subregional mean values

To calculate a geometric mean value for each EUR subregion, we used the sample-size weighted geometric mean values for all countries within the subregion. The subregional mean value was also disaggregated into mean values for countries with and without lead-prevention activity. These means were weighted as for the country mean values, with the exception that the child population of the country was used as input instead of the study sample size. The output of this step included a single population-weighted geometric mean for each EUR subregion, by out-phased/non out-phased country groups. The reduction factor was used only for countries with a lead-prevention programme, and only if the country mean value had not been adjusted previously. The out-phased and non out-phased geometric means were then combined to give a single geometric mean for each EUR subregion.

4.2.5 Standard deviation

A single subregional standard deviation (SD) was calculated from the sample sizes of individual studies carried out in the countries of the subregion.

4.2.6 Calculating the incidence of mild mental retardation and the distribution of blood lead levels

MMR occurs within the relatively narrow IQ range of 50–70 points, therefore children who lose IQ points, yet whose IQ remains above the IQ 70 threshold, were not included in our analysis. Clearly, the children most at risk are those whose IQ is close to the upper range, or threshold, for MMR.

To calculate the incidence of health effects (in this case, MMR) for each EUR subregion, we used the Microsoft Excel spreadsheet developed and distributed by the WHO Department of Protection of the Human Environment (WHO, 2003). The loss of IQ points was first associated with BLL according to reports in the literature (Fewtrell, Kaufmann & Prüss-Üstün, 2003). Due to the scarcity of studies reporting BLL in rural populations, data were combined for studies reporting both urban and rural BLL. Analyses were also performed for urban and rural populations separately, but the results are not presented in detail. The log–normal distribution of BLL in the population was obtained using the function LOGNORMDIST in the Excel spreadsheet (Input: mean BLL, standard deviation, BLL above which the health effect occurs). 1- LOGNORMDIST gives the proportion of the population above a certain BLL. This step was repeated for each BLL above a given value (5 μg/dl, 10 μg/dl, 15 µg/dl, etc.). From these data we calculated the number of children in each BLL interval, and hence the number of children with the associated loss of IQ points.

The IQ loss rates were converted into MMR incidence by multiplying the number of children with IQ losses in each BLL interval, by the percentage of the population in the IQ interval, summing the results and multiplying by the regional adjustment ratio. The result, multiplied by 1000, gives the rate of illness per 1000 children. The MMR incidence was input into the DALY Excel calculation template for MMR developed by WHO (WHO, 2003). Since there are no YLL for mild mental retardation, total DALYs were equal to YLD. The calculation of DALYs included a discount for health of 3% per year and age weighting to ensure comparability with other GBD studies.

4.2.7 Sensitivity analysis

As part of a sensitivity analysis, upper and lower estimates of MMR incidence were calculated as follows. A lower estimate of the BLL was calculated assuming all countries had a lead reduction programme in place, and adjusting all mean lead levels accordingly (i.e. all studies from countries without lead reduction programmes were assumed to have a programme in place by 1998). The upper estimate of BLL assumed that no countries had lead prevention programmes, and means were estimated without applying reduction factors. The BLL upper and lower limits were then used to calculate the MMR incidence and DALYs. The corresponding incidence rates were used to calculate upper and lower estimates of DALYs.

4.3 Results

Estimates of the mean BLL, by subregion, are shown in Table 4.1:

Table 4.1 Blood lead levels in children 0–4 years old, by subregion.

Blood lead measurements	Subregion EUR A	 EUR B	 EUR C
Subregional mean BLL (µg/dl)	1.9[a] 2.9[b] 3.8[c]	3.1 3.9 4.4	4.3 4.3 6.4
Standard Deviation (µg/dl)	1.5	1.6	2.4
Children with >5 µg/dl blood lead (%)	3.3 9.4 24.9	11.5 28.2 38.7	48.6 42.8 61.0
Children with >10 µg/dl blood lead (%)	0 0.1 0.9	0.1 1.6 3.2	21.5 16.9 31.7
Children with >20 µg/dl blood lead (%)	0 0 0	0 0 0	6.2 4.1 11.0
Countries for which recent data are available	Croatia[1] Czech Republic[2] Finland[3] France[4] Germany[5] Greece[6] Italy[7] Portugal[8] Spain[9] Sweden[10] UK[11]	Armenia[12] Bulgaria[13] Poland[14] Turkey[15] Yugoslavia[16]	Hungary[17] Russian Federation[18]

[a] lower estimate, assumes lead prevention programmes had been in force in all countries since 1998; [b] best estimate, based on actual country data; [c]upper estimate, assumes no lead prevention activity.

[1] Prpic-Majic et al. (2000); [2]Benes et al. (2001), Zimova et al. (2001); [3]Ponka (1998); [4]Flurin et al. (1998), Leroyer et al. (2000); [5]Wilhelm et al. (2002); [6]Maravelias et al. (1994); [7]Menditto et al. (1998); [8]Mayan et al. (2001); [9]Sole et al. (1998), Garcia-Algar et al. (2003); [10]Berglund et al. (2000); [11]O'Donohoe et al. (1998); [12]Saryan (1995); [13]Bainova (1995), Fischer et al. (2003); [14]Zejda et al. (1997), Osman et al. (1998); [15]Furman et al. (1999); [16]Factor-Litvak et al. (1996); [17]Bitto et al. (1997), Hassanien et al. (1999); [18]Rubin et al. (1997).

BLL were highest in EUR C with a mean of 4.3 µg/dl (SD = 2.4 µg/dl). According to the estimates, 17% of children 0–4 years of age in EUR C (approximately 1.9 million children) have BLL higher than 10 µg/dl, and 4% have BLL higher than 20 µg/dl. Based on these exposure levels, three cases of MMR are expected for every 1000 children in the age group 0–1 year. The MMR incidence in the age group 0–4 years is one fifth this rate.

The mean BLL in EUR B was 3.9 µg/dl. Based on this value, only 2% of children in the age group 0–4 years in EUR B (approximately 360 000 children) would have BLL greater than 10 µg/dl, whereas no children would have BLL greater than 20 µg/dl. This translates into little more than one case of MMR per 1000 children in the age group 0–1 year. A lower estimate assuming all countries in EUR B had lead prevention programmes in place would reduce the incidence rate by almost 50% (Table 4.2).

Table 4.2 Loss of IQ points, MMR and DALYs in children 0–4 years of age caused by environmental exposure to lead, for 2001

	Subregion		
	EUR A	**EUR B**	**EUR C**
Loss of IQ points (No. of children affected per 1000 children)			
Loss of 0.65 IQ points	93	266	293
Loss of 1.95 IQ points	1	15	130
Loss of 3.25 IQ points	0	1	64
Loss of 3.5 IQ points	0	0	93
Total no. children with loss of 0.65 IQ points or more (rate per 1000 children)	94	282	580
MMR (incidence per 1000 children)			
Lower estimate[a]	<0.01	0.11	0.61
Best estimate	0.05	0.24	0.61
Upper estimate	0.13	0.35	1.06
MMR DALYs (thousands)			
Lower estimate	1	25	88
Best estimate	14	55	88
Upper estimate	36	80	153

[a] The lower estimate assumes that lead prevention programmes had been in force in all countries since 1998; the best estimate is based on actual country data; and the upper estimate assumes there is no lead prevention activity.

Mean BLL were lowest in EUR A (Table 4.1). Based on this exposure, mean BLL exceeded 10 µg/dl in only 0.1% of the population and 20 µg/dl in none. These estimates predict an MMR incidence of less than one case of MMR per 1000 children in the age group 0–1 year (Table 4.2).

A sensitivity analysis of the results was performed by calculating upper and lower estimates of the disease burden, assuming the absence or presence of lead-prevention activity, respectively (Tables 4.1 and 4.2).

Figure 4.1 DALYs due to MMR, assuming lead-prevention activity

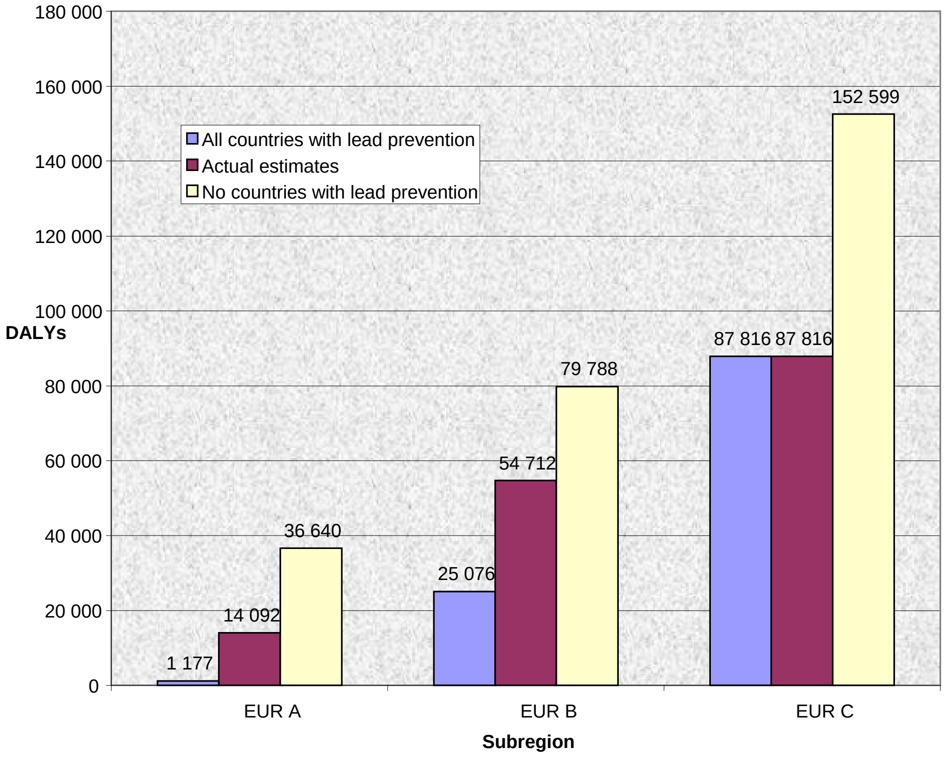


Table 4.3 summarizes the number of DALYs attributable to MMR for children in the age group 0–4 years. Approximately 1.4% of all-cause DALYs (children 0–4 years old) in the European Region can be attributed to lead-induced MMR. The number of DALYs attributable to MMR were lowest in EUR A.

If we had estimated the burden of disease due to lead by analysing separately urban and rural BLL, the total number of DALYs in the European Region would have been higher (approximately 480 000 DALYs), with EUR B carrying a higher burden (300 000 DALYs) than EUR A (40 000 DALYs) and EUR C (140 000 DALYs).

Table 4.3 The burden of mild mental retardation in children 0–4 years old attributable to blood lead, for EUR

Subregion	DALYs	% of all-cause DALYs	DALYs per 10 000 children
EUR A	14 092	0.8	6.3
EUR B	54 711	0.9	30.4
EUR C	87 816	3.1	77.4
Totals, EUR	156 619	1.4	3.0

4.4 Discussion

Few studies outside of the USA have been performed on a regional basis to determine the environmental exposure and risk of lead poisoning in children. In the European Region, this task is daunting given the wide range of political, economic and health systems that govern environmental monitoring. This study was therefore undertaken as a first step in quantifying the risk and health impact of environmental lead exposure in the European child population.

There are several limitations to this study. First, the methods and techniques used by studies to collect the data varied, as did the study settings. As a result, only one third of the studies found in the literature satisfied our criteria for inclusion in the estimates. The studies were significantly weighted toward EUR A, with a paucity of studies from EUR C. A major exclusion factor was language and access to data. Although most studies published in peer reviewed MEDLINE journals were written in languages included in our criteria, a few were not (e.g. Polish, Russian, Dutch and German). In addition, it was difficult to access the journals in which these studies were published. The web sites of some health ministries were also often written in the local language, further limiting access to potentially useful data.

Most studies were eliminated because they were performed on populations in contaminated areas, or lacked precise information on the number of exposed people. Another limiting factor was that many studies were performed in the early 1990s, when the initial studies on lead exposure and its health effects were published. Many countries, especially those in EUR B and EUR C, had not yet implemented lead-reduction measures for industry and vehicular emissions. Since the early 1990s, however, a few countries have initiated routine lead monitoring, although this information is not available in the published literature or via the internet (especially in less-developed countries).

Rural populations were the least studied, since it is assumed the populations have a lower risk of exposure to lead, and these populations are not represented in some regions. In many studies, it was unclear if samples were taken in rural or urban settings. For this reason, we combined values in studies reporting rural and urban BLL, which could lead to error in the estimates. In addition, the population sampling methodology of a study may have missed pockets of the general population. Each of these factors could lead to underestimates or overestimates of BLL. As an example, if urban and rural areas had been analysed separately, rural estimates of BLL would have been even greater than those presented here, particularly in EUR A and EUR B, where two small studies showed that rural child populations have high BLL (Maravelias et al., 1994; Fischer et al., 2002). The number of DALYs in the European Region would also have been approximately three times higher, and the burden of disease from lead exposure would have represented 4.4% of all-cause DALYs in the European Region, instead of 1.4%.

We estimated that BLL would be reduced by 7.8% per year if a country had lead-prevention activities in place. This value was based on studies in the literature that estimated a reduction of 30–48% over a five-year period. We took the midpoint

(39%), but this value may not apply to all countries, depending on the speed with which lead-prevention activity is implemented. We also used a 50% or more market share of unleaded gasoline as a surrogate for lead prevention activity (Lovei, 1998; UNECE, 2000, 2003; Walsh, 2003), which is a potential source of error in estimates of the lead prevention activity in 2001. Other potential sources of error in our estimates include discrepancies in the reporting of consumption, maximum lead levels and market share between agencies furnishing data, and the absence of data from Central Asia and Eastern Europe (UNEP, 1998).

As part of the sensitivity analysis based on level of lead prevention activity, we chose 1998 as the date of implementation of activity in all countries for the lower estimates. The choice of this date was based on information from the 1998 report of the Fourth Ministerial Conference Environment for Europe, which detailed implementation activity and strategy for phasing out leaded petrol in Europe (UNECE, 2000). However, even though this date may have signalled firm commitment on the part of many of the participating countries, it is unclear as to how quickly interventions in each country were instituted.

One of the most important factors to note in interpreting the estimates from this study is the classification system used to define the subregions. Whereas the WHO classification, based on levels of child and adult mortality, may be important in assessing certain health-related issues, environmental exposures are more often defined by the political, demographic and economic structure of the country. For example, industry and urban development are closely associated with high levels of lead exposure (Lovei, 1997), though other factors may counterbalance this effect. In addition, the health effects associated with IQ are particularly sensitive to socioeconomic factors and may not be accounted for in the mortality classifications. Therefore, when interpreting estimates by subregion in this study, we must also consider the basis of the data by individual country.

This is most notable for countries in EUR B and EUR C, where the classification is based on differences in the level of adult mortality, which may or may not be significantly influenced by the socioeconomic structure of the country. We found BLL were highest in EUR C based on data from two countries — the Russian Federation and Hungary (World Bank, 2003c). These countries are very different in terms of their economic development and demographic structure, and even though the total and urban population of the Russian Federation is over 10 times larger, it has a GDP per capita one half that of Hungary (World Bank, 2003c). The Russian Federation also has a highly concentrated industrial structure, which contributes to a greater risk of lead exposure. Hungary, on the other hand, has a smaller urban population, and much less poverty and industrial development, but is classified in EUR C along with the Russian Federation (World Bank, 2003c). Weighting BLL from studies in these two countries by population size raises the mean BLL for the whole EUR C subregion, since a greater weighting is applied to data from the Russian Federation, which has higher BLL. This illustrates why it is necessary to consider country-level data when interpreting burden of disease estimates.

In EUR B, the estimated mean BLL was relatively low. This reflects the fact that a study in Turkey (Furman & Laleli, 1999) reported BLL (3.5 µg/dl) lower than other studies in the subregion (all >5 µg/dl). The mean BLL for the EUR B subregion may therefore be skewed towards Turkey, because of its large child population and the impact this has on weighting the data.

In the sensitivity analyses, the upper estimates of MMR incidence and DALYs in EUR C were over 100 times higher than the lowest estimates in EUR A. Since reductions in the use of leaded gasoline and in industrial lead emissions have been shown to correspond to reductions in BLL, significant decreases in the burden of disease could be achieved in EUR C with a complete phase-out of lead in gasoline and the abatement of lead emissions. Similarly, improvements in the socioeconomic structure of EUR C could have a profound impact on the risk of development of MMR and thus reduce the number of DALYs lost to this disease even further.

The loss of just a few IQ points, as occurs with lead exposures, has only a relatively small impact on mental abilities. However, people with an IQ of about 70 (the threshold for MMR) are particularly vulnerable, since even the loss of a few IQ points may cause MMR in these individuals. Thus, the impact on health of lead exposure may be particularly hard in this population. In this study, we considered only IQ loss that results in values lower than 70 points, thus fulfilling the definition of MMR. However, a much larger portion of the population loses IQ points which may indirectly impact health and functioning, even though it does not result in MMR. For this reason, the burden of disease due to lead that we have calculated is likely to be an underestimate.

4.5 Conclusions

We estimated that approximately 157 000 DALYs were associated with lead-caused MMR in the European Region, and that lead accounts for 1.4% of all-cause DALYs in the Region. EUR C was the most significant contributor to the total burden of lead-associated disease in the Region. However, the differences in DALYs among the three subregions are smaller in the case of MMR due to lead exposure, than for diseases due to other environmental factors (e.g. indoor air pollution, or water, sanitation and hygiene).

5. Injuries

5.1 Introduction

Childhood injuries are a significant public-health problem in Europe, particularly in countries of central and eastern Europe and in the Newly Independent States (NIS) (Tamburlini, Ehrenstein & Bertollini, 2002; Koupilova, Lang & Leon, 2003). In 1996, the average mortality from external causes for children 1−14 years of age was 4.5 times higher in the NIS than in the EU, and 2.4 times higher in central and eastern Europe than in the EU (Koupilova, Lang & Leon, 2003). Differences in childhood injury rates have also been reported within the EU (Sibert & Stone, 1998; Ellsasser & Berfenstam, 2000; Petridou, 2000; Vincenten, 2001). Many factors may contribute to the variation, for example socioeconomic factors are known to play a role (Plitponkarnpim et al., 1999; Lyons et al., 2003). Differences in child safety interventions and regulations are also important (Sibert & Stone, 1998). Although mortality rates from childhood injury have declined in many European countries over the past decade (Petridou, 2000; Vincenten, 2001; Koupilova, Lang & Leon, 2003; Parkkari, Niemi & Kannus, 2003), injury remains the leading cause of childhood death in the EU (Vincenten, 2001).

The aim of this section is to provide an updated overview of the burden of injuries borne by children of the three European subregions (EUR A, EUR B and EUR C), and to evaluate the number of child deaths and DALYs that could be prevented in each subregion. It should be noted that we present the burden of all injuries, not just those attributable to the physical environment in the strict sense. Injuries can arise from many factors, including those related to humans, and to the physical, social and economic environments (Runyan, 1998). Even intentional injuries can be environmentally related. A typical example of this is injury due to war, its main risk factor being involvement in a conflict.

Data presented in this section underscore the size of the burden of all injuries borne by children and adolescents in the European Region, and illustrate geographical and age-related differences that should be considered when targeting interventions.

5.2 Methods

The fraction of deaths and DALYs attributable to injuries was calculated using data from the *Global Burden of Disease 2001 Estimates* (WHO, 2001). Estimates of the burden of injury are presented by subregion, sex, age group (0–4, 5–14, 15–19 years), and type of injury.

Unintentional injuries include:

- road traffic accidents (ICD-9 codes E810–E819, E826–E829);
- poisonings (E850–E869);
- falls (E880–E888);

- drownings (E910);
- other unintentional injuries (E800–E807, E820–E848, E870–E879, E900–E909, E911–E949).

Intentional injuries include:

- self-inflicted injuries (E950–E959);
- violence (E960–E969);
- war (E990–E999);
- other intentional injuries (E970–E978).

5.3 Results

5.3.1 Deaths

In 2001, all-cause injuries were responsible for approximately 13 000 deaths in children 0–19 years of age in EUR A (an average of 1.4 deaths per 10 000 children), corresponding to 30% of the total burden of mortality in that age group in the subregion. In EUR B, all-cause injuries were responsible for approximately 19 000 deaths (an average of 2.4 deaths per 10 000 children), which corresponded to 11% of the total burden of mortality born by children 0–19 years of age. In EUR C, all-cause injuries caused almost 43 000 deaths (average, 6.6 deaths per 10 000 children), 39% of the total burden of child mortality in the subregion (Tables 5.1–5.3).

In all three subregions, the highest proportion of deaths attributable to injuries was among teenagers (15–19 years of age). However, the proportion was much higher in EUR C (39%) and EUR A (30%), than in EUR B (11%). In all three subregions, the proportion of deaths attributable to injuries was higher among males than among females.

Most injury deaths were caused by unintentional injuries: 76% in EUR A, 81% in EUR B, and 67% in EUR C. In all three subregions, the fraction of deaths caused by unintentional injuries decreased with increasing child age (Figure 5.1), with no relevant differences between males and females. Among unintentional injury deaths, the relative frequency of external causes was different in each subregion (Figures 5.2–5.4). For example, road traffic accidents accounted for a much higher proportion of unintentional injury deaths in EUR A than in the other two subregions. In EUR C, there was a particularly high proportion of deaths due to poisonings and fires. Drowning accounted for a similar proportion of unintentional injury deaths among the youngest children in the three subregions, but among those 5–19 years of age, the proportion of deaths caused by drowning was much higher in EUR B and EUR C (where this type of injury caused the highest fraction of deaths among children in the age group 5–14 years) than in EUR A. Despite these differences among subregions, there were some similarities. For example, in all three subregions, the proportion of unintentional injury deaths due to road traffic accidents increased with child age, whereas the proportion of deaths attributable to fires decreased with age.

Self-inflicted injuries were an important cause of death only for children 5−19 years of age, and in the 15−19 year age group such injuries represented the most common cause of intentional injury death. In EUR B and EUR C, war was a more frequent cause of death at any age than in EUR A (Figures 5.5−5.7).

5.3.2 DALYs

In the year 2001, injuries were responsible for approximately 895 000 DALYs among children in EUR A, 1 528 000 DALYs in EUR B, and 2 371 000 DALYs in EUR C (Tables 5.4–5.6). In EUR A, 84% of those DALYs were due to unintentional injuries (96% among children 0–4 years old, 88% among those 5−14 years old, and 78% among those 15−19 years old). In EUR B, unintentional injuries were responsible for 86% of the DALYs (96% among children 0–4 years old, 91% among those 5−14 years old, and 73% among those 15−19 years old). In EUR C unintentional injuries were responsible for 70% of the DALYs (91% among children 0–4 years old, 81% among those 5−14 years old, and 59% among those 15−19 years old).

In all subregions and age groups, the proportion of all DALYs that is attributable to unintentional injury from road traffic accidents was smaller than the proportion of all deaths due to that cause. In contrast, the proportion of all DALYs attributable to falls was higher than the proportion of all deaths due to that cause. In other words, road traffic accidents are responsible for more deaths than disability, as a proportion of unintentional injuries, compared to falls, which cause a greater proportion of disability.

In all subregions, the proportion of all DALYs attributable to self-inflicted injuries among teenagers was lower than the corresponding proportion for all deaths, whereas the proportion of DALYs from violence was higher than the corresponding proportion for deaths. In EUR B and EUR C, the proportion of all DALYs attributable to war was much higher than the corresponding proportion of all deaths, particularly among the youngest children. In fact, war was responsible for almost 7 000 DALYs among children 0–4 years old, in both EUR B and in EUR C, but was responsible for fewer than 100 DALYs among children of the same age in EUR A. Figures 5.8−5.13 show the number of DALYs attributable to various types of intentional and unintentional injuries, by subregion and by child age group. A summary of the deaths and DALYs attributable to injuries is given in Table 5.7 for the three European subregions.

Table 5.1 Injury deaths by age and sex, EUR A, year 2001

	Males				Females				Males and Females			
Age (years)	**0–4**	**5–14**	**15–19**	**0–19**	**0–4**	**5–14**	**15–19**	**0–19**	**0–4**	**5–14**	**15–19**	**0–19**
Cause:												
All causes	12 674	3 730	11 681	28 085	9 909	2 603	3 950	16 461	22 583	6 332	15 631	44 547
Injuries	**934**	**1 545**	**7 640**	**10 120**	**656**	**821**	**1 853**	**3 330**	**1 591**	**2 366**	**9 492**	**13 450**
Unintentional injuries	***855***	***1 374***	***5 361***	***7 590***	***592***	***717***	***1 292***	***2 600***	***1 447***	***2 091***	***6 653***	***10 191***
Road traffic accidents	237	773	4 013	5 022	188	445	1 009	1 642	425	1,217	5 021	6 663
Poisonings	18	13	343	373	14	19	71	104	32	32	414	478
Falls	50	61	208	319	43	26	38	108	94	88	246	427
Fires	64	56	62	182	34	31	21	87	98	87	083	269
Drownings	153	135	165	454	74	49	20	142	227	184	186	596
Others	333	336	571	1 240	238	147	133	518	571	483	704	1 758
Intentional injuries	***79***	***172***	***2 279***	***2 529***	***65***	***104***	***561***	***729***	***144***	***276***	***2 839***	***3 259***
Self-inflicted injuries	0	106	1 914	2 020	0	47	453	500	0	152	2 367	2 519
Violence	78	57	242	376	64	53	102	219	142	110	344	596
War	1	8	120	129	1	4	5	10	2	12	125	139
Others	0	2	3	5	0	0	0	0	0	2	3	5

Table 5.2 Injury deaths by age and sex, EUR B, year 2001

	Males				Females				Males and Females			
Age (years)	**0–4**	**5–14**	**15–19**	**0–19**	**0–4**	**5–14**	**15–19**	**0–19**	**0–4**	**5–14**	**15–19**	**0–19**
Cause:												
All causes	78 391	9 607	12 825	100 823	63 036	6 979	6 256	76 271	141 427	16 586	19 081	177 094
Injuries	**3 148**	**3 324**	**6 694**	**13 166**	**2 377**	**1 764**	**1 627**	**5 767**	**5 524**	**5 087**	**8 322**	**18 933**
Unintentional injuries	***3 116***	***2 957***	***4 483***	***10 556***	***2 333***	***1 447***	***1 028***	***4 808***	***5 449***	***4 404***	***5 511***	***15 364***
Road traffic accidents	442	811	1,506	2 759	408	472	361	1 241	850	1 283	1 867	4 000
Poisonings	117	75	242	434	142	101	95	338	260	176	337	773
Falls	194	145	184	523	122	70	41	233	316	215	225	756
Fires	277	75	105	458	244	73	90	407	521	148	196	865
Drownings	557	652	409	1 619	311	274	90	674	868	926	499	2 293
Others	1 529	1 198	2 037	4 764	1 105	458	350	1 913	2 633	1 656	2 387	6 677
Intentional injuries	***31***	***367***	***2 211***	***2 610***	***44***	***316***	***599***	***960***	***75***	***683***	***2 811***	***3 569***
Self-inflicted injuries	0	266	1 343	1 610	0	246	462	708	0	512	1 806	2 318
Violence	28	83	597	707	40	62	122	224	68	145	719	931
War	2	17	250	269	2	9	11	21	4	25	261	290
Others	1	1	21	24	2	0	4	6	3	1	26	30

Table 5.3 Injury deaths by age and sex, EUR C, year 2001

	Males				**Females**				**Males and Females**			
Age (years)	**0–4**	**5–14**	**15–19**	**0–19**	**0–4**	**5–14**	**15–19**	**0–19**	**0–4**	**5–14**	**15–19**	**0–19**
Cause:												
All causes	30 045	9 792	34 164	74 001	22 139	5 073	9 076	36 288	52 184	14 865	43 240	110 289
Injuries	**3 319**	**5 805**	**24 129**	**33 253**	**2 440**	**2 320**	**4 762**	**9 523**	**5 759**	**8 125**	**28 892**	**42 776**
Unintentional injuries	***3 063***	***4,791***	***13 853***	***21 707***	***2 149***	***1 888***	***2 920***	***6 957***	***5 212***	***6 679***	***16 773***	***28 664***
Road traffic accidents	256	1 251	4 065	5 571	203	633	1 171	2 006	458	1 884	5 236	7 578
Poisonings	472	489	3 753	4 714	366	228	743	1 337	838	717	4 496	6 051
Falls	170	230	589	989	122	64	159	345	292	294	748	1 334
Fires	849	507	966	2 322	651	164	151	966	1 500	671	1 117	3 288
Drownings	517	1 460	1 595	3 572	271	531	278	1 080	788	1 991	1 873	4 652
Others	799	855	2 884	4 538	537	267	419	1 223	1 336	1 123	3 303	5 761
Intentional injuries	***256***	***1 014***	***10 276***	***11 546***	***292***	***432***	***1 842***	***2 566***	***548***	***1 446***	***12 118***	***14 112***
Self-inflicted injuries	00	625	5 472	6 096	0	146	829	975	0	770	6 301	7 071
Violence	202	260	3 111	3 572	205	226	932	1 363	407	485	4 043	4 935
War	16	110	1 651	1 777	11	57	74	142	27	167	1 725	1 919
Others	38	20	43	101	76	4	6	86	114	23	49	187

Table 5.4 Injury DALYs by age and sex, EUR A, year 2001

	Males				**Females**				**Males and Females**			
Age (years)	**0–4**	**5–14**	**15–19**	**0–19**	**0–4**	**5–14**	**15–19**	**0–19**	**0–4**	**5–14**	**15–19**	**0–19**
Cause:												
All causes	923 729	813 791	1 469 597	3 207 117	784 648	733 876	1 264 989	2 783 513	1 708 377	1 547 668	2 734 587	5 990 631
Injuries	**75 520**	**181 743**	**355 322**	**612 585**	**53 185**	**117 173**	**112 003**	**282 361**	**128 705**	**298 916**	**467 325**	**894 947**
Unintentional injuries	***72 572***	***159 377***	***273 723***	***505 672***	***50 871***	***104 217***	***90 430***	***245 518***	***123 443***	***263 594***	***364 153***	***751 190***
Road traffic accidents	10 536	40 253	163 489	214 278	9 080	25 903	45 833	80 816	19 616	66 155	209 322	295 094
Poisonings	880	1 063	11 752	13 695	785	1 203	3 000	4 988	1 665	2 266	14 752	18 683
Falls	16 061	32 228	34 857	83 146	12 210	15 617	11 097	38 924	28 270	47 845	45 953	122 069
Fires	4 278	3 354	3 305	10 937	2 234	1 515	914	4 663	6 511	4 869	4 220	15 600
Drownings	5 629	5 121	5 745	16 496	2 879	1 882	741	5 501	8 508	7 002	6 486	21 997
Others	35 188	77 358	54 575	167 121	23 684	58 097	28 845	110 625	58 872	135 455	83 420	277 747
Intentional injuries	***2 948***	***22 367***	***81 598***	***106 913***	***2 314***	***12 956***	***21 574***	***36 844***	***5 262***	***35 323***	***103 172***	***143 757***
Self-inflicted injuries	0	17 472	64 432	81 904	0	9 354	16 473	25 827	0	26 826	80 905	107 730
Violence	2 907	4 536	13 092	20 535	2 287	3 174	4 919	10 380	5 193	7 710	18 012	30 915
War	041	299	3 949	4 290	28	429	181	637	69	728	4 130	4 927
Others	0	59	125	185	0	0	0	0	0	59	126	185

Table 5.5 Injury DALYs by age and sex, EUR B, year 2001

	Males				Females				Males and Females			
Age (years)	**0–4**	**5–14**	**15–19**	**0–19**	**0–4**	**5–14**	**15–19**	**0–19**	**0–4**	**5–14**	**15–19**	**0–19**
Cause:												
All causes	3 548 708	1 193 389	1 311 021	6 053 117	2 889 189	954 075	1 137 618	4 980 882	6 437 897	2 147 464	2 448 639	11 034000
Injuries	**239 006**	**454 153**	**415 139**	**1 108 298**	**129 142**	**185 705**	**104 892**	**419 739**	**368 149**	**639 858**	**520 031**	**1 528 037**
Unintentional injuries	***230 174***	***424 197***	***302 828***	***957 199***	***124 733***	***156 183***	***77 807***	***358 723***	***354 907***	***580 379***	***380 636***	***1 315 922***
Road traffic accidents	18 185	46 666	64 447	129 299	17 843	31 798	17 963	67 604	36 028	78 465	82 410	196 903
Poisonings	4 212	3 285	8 288	15 785	5 056	4 197	3 589	12 841	9 268	7 481	11 877	28 626
Falls	40 837	92 828	46 968	180 633	20 686	28 941	10 111	59 738	61 523	121 769	57 079	240 370
Fires	28 819	17 425	9 548	55 792	13 441	8 042	4 423	25 905	42 260	25 467	13 971	81 698
Drownings	19 643	24 423	13 982	58 048	11 023	10 336	3 249	24 608	30 666	34 759	17 231	82 656
Others	118 477	239 569	159 596	517 642	56 685	72 869	38 473	168 027	175 162	312 439	198 068	685 669
Intentional injuries	***8 832***	***29 956***	***112 311***	***151 099***	***4 409***	***29 522***	***27 085***	***61 016***	***13 241***	***59 478***	***139 395***	***212 115***
Self-inflicted injuries	0	15 277	48 939	64 216	0	12 892	16 951	29 843	0	28 170	65 890	94 059
Violence	1 597	9 998	38 769	50 364	1 523	6 541	8 930	16 994	3 120	16 539	47 699	67 358
War	6 746	4 503	23 565	34 813	65	10 077	1 059	11 202	6 810	14 580	24 624	46 015
Others	490	177	1 038	1 705	2 821	12	144	2 977	3 311	189	1 182	4 682

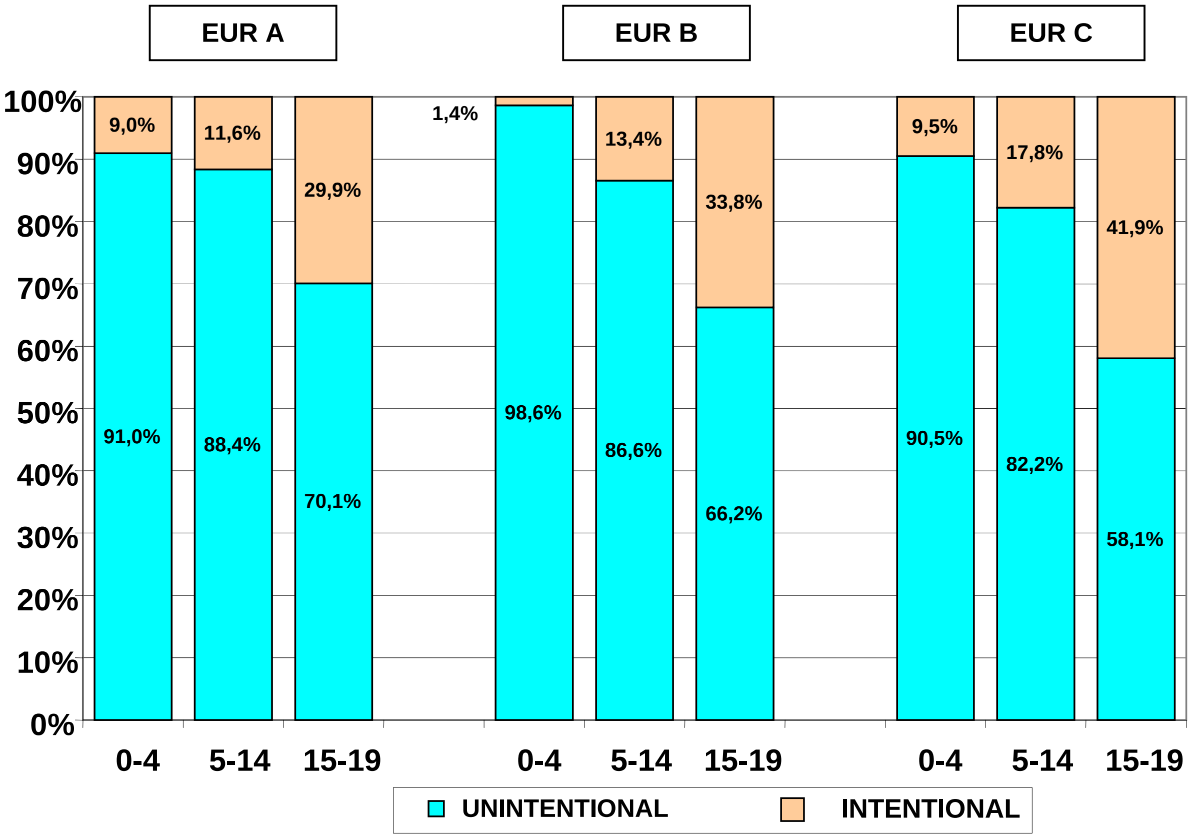
Table 5.6 Injury DALYs by age and sex, EUR C, year 2001

	Males				**Females**				**Males and Females**			
Age (years)	**0–4**	**5–14**	**15–19**	**0–19**	**0–4**	**5–14**	**15–19**	**0–19**	**0–4**	**5–14**	**15–19**	**0–19**
Cause:												
All causes	1 637 017	1 192 336	2 189 491	5 018 845	1 214 438	716 803	1 183 723	3 114 964	2 851 455	1 909 139	3 373 215	8 133 808
Injuries	**195 489**	**518 382**	**1 079 380**	**1 793 250**	**113 077**	**213 901**	**250 345**	**577 323**	**308 566**	**732 282**	**1 329 725**	**2 370 573**
Unintentional injuries	***180 011***	***431 175***	***628 046***	***1 239 233***	***101 986***	***162 682***	***158 828***	***423 496***	***281 997***	***593 857***	***786 874***	***1 662 729***
Road traffic accidents	12 006	70 196	170 113	252 315	10 348	45 458	59 377	115 183	22 354	115 653	229 490	367 498
Poisonings	16 539	18 646	123 793	158 978	12 883	8 921	25 305	47 108	29 422	27 566	149 098	206 086
Falls	27 288	80 769	69 363	177 420	15 225	27 127	20 730	63 083	42 513	107 897	90 093	240 503
Fires	41 293	39 563	40 988	121 844	25 102	10 188	6 549	41 839	66 395	49 752	47 537	163 683
Drownings	18 196	54 479	53 271	125 946	9 609	19 974	9 645	39 228	27 805	74 453	62 915	165 173
Others	64 689	167 522	170 519	402 731	28 819	51 014	37 222	117 055	93 508	218 536	207 741	519 785
Intentional injuries	***15 478***	***87 206***	***451 333***	***554 018***	***11 091***	***51 219***	***91 517***	***153 827***	***26 569***	***138 425***	***542 850***	***707 844***
Self-inflicted injuries	0	47 539	190 164	237 704	0	13 269	30 687	43 956	0	60 808	220 851	281 660
Violence	7 884	31 708	191 153	230 746	7 519	19 629	57 011	84 159	15 403	51 337	248 164	314 905
War	6 184	7 176	68 231	81 591	394	18 187	3 596	22 177	6 578	25 363	71 828	103 768
Others	1 409	783	1 784	3 976	3 178	134	223	3 535	4 588	917	2 007	7 511

Table 5.7 Burden of injury in Europe, children 0–19 years of age, 2001

	Deaths			**DALYs**		
Subregion	**Deaths**	**% of all-cause deaths**	**Deaths per 10 000 children**	**DALYs**	**% of all-cause DALYs**	**DALYs per 10 000 children**
EUR A	13 450	30.2	1.4	894 947	14.9	94.2
EUR B	18 933	10.7	2.4	1 528 037	13.8	192.5
EUR C	42 776	38.8	6.6	2 370 573	29.1	365.6
Burden for WHO European Region	75 159	22.6	3.1	4 793 557	19.0	200.4

Figure 5.1 Proportion of deaths from unintentional and intentional injuries, by age group and European subregion, year 2001



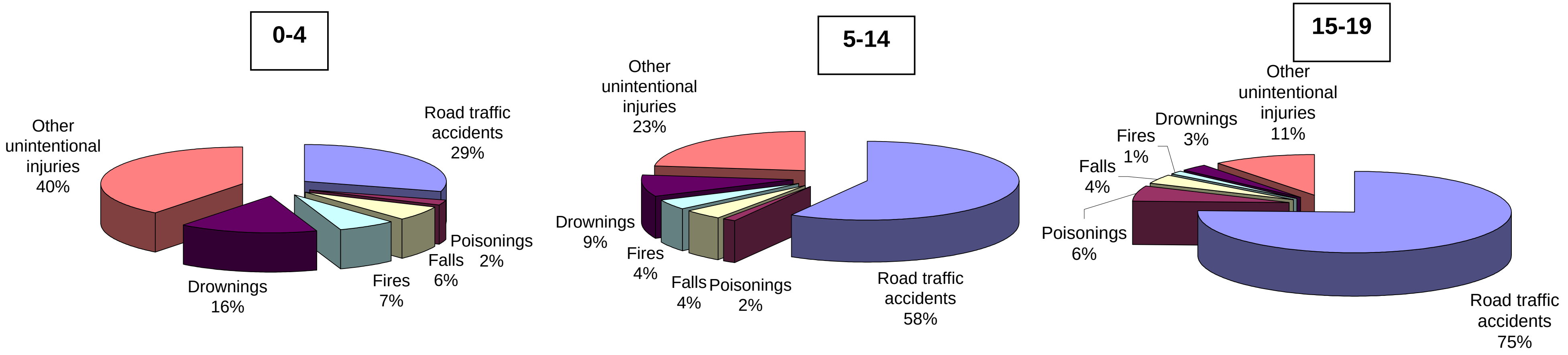


Figure 5.2 Proportion of deaths from external causes of unintentional injury, by age group, EUR A

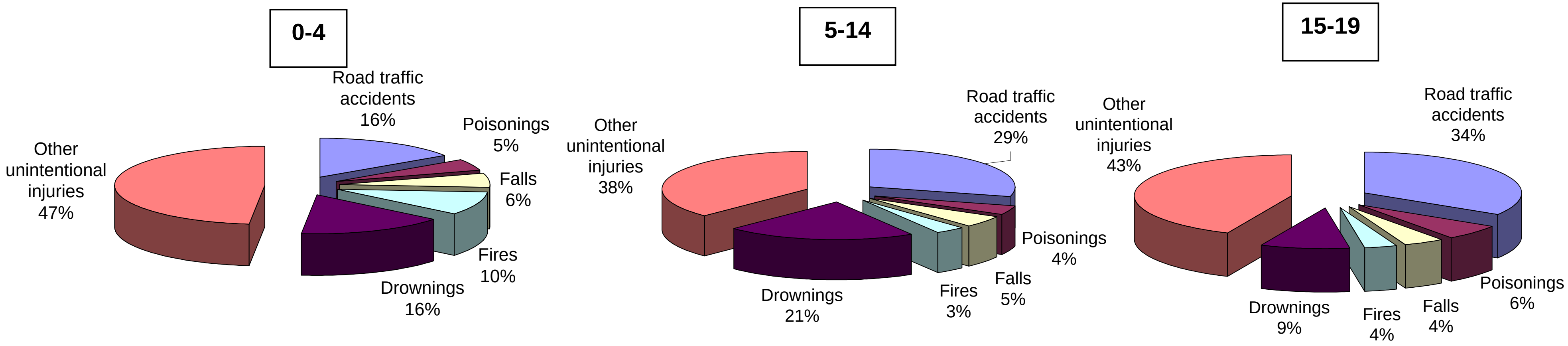


Figure 5.3 Proportion of deaths from external causes of unintentional injury, by age group, EUR B.

Figure 5.4 Proportion of deaths from external causes of unintentional injury, by age group, EUR C

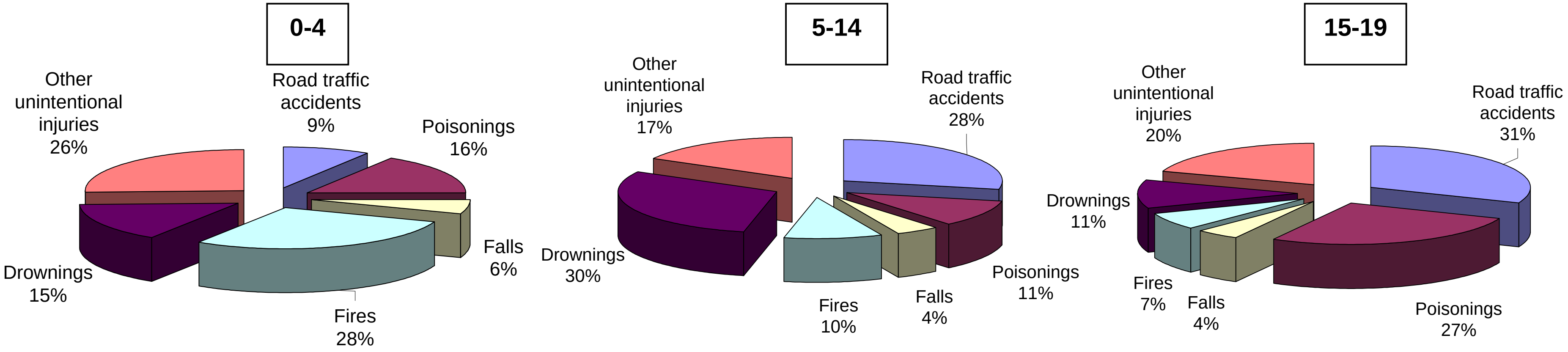


Figure 5.5 Proportion of deaths from external causes of intentional injury, by age group, EUR A

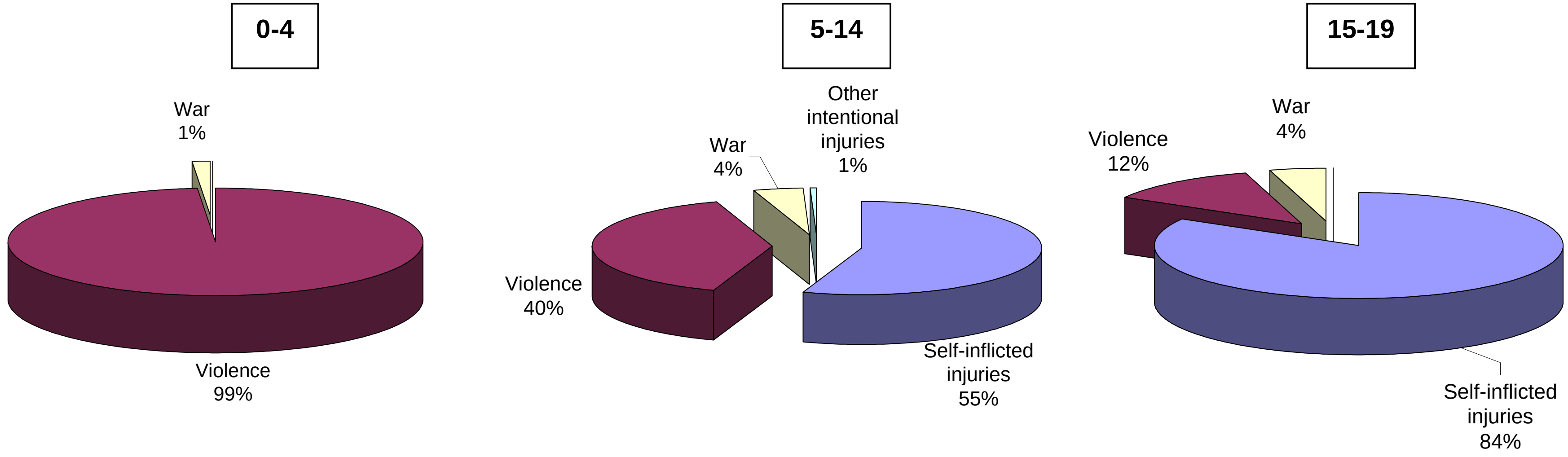


Figure 5.6 Proportion of deaths from external causes of intentional injury, by age group, EUR B

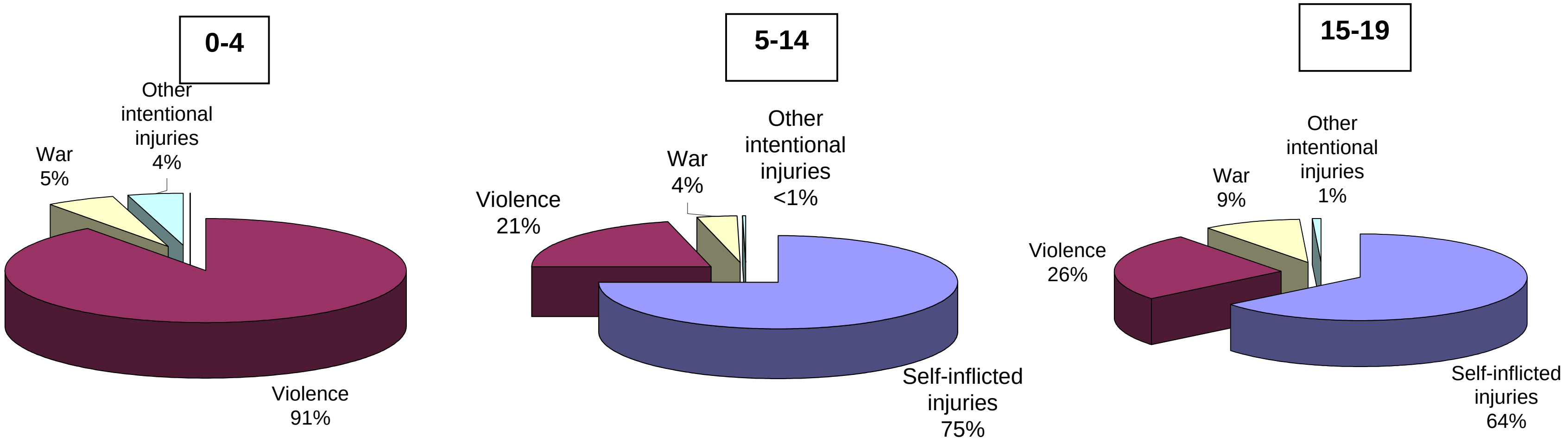


Figure 5.7 Proportion of deaths from external causes of intentional injury, by age group, EUR C

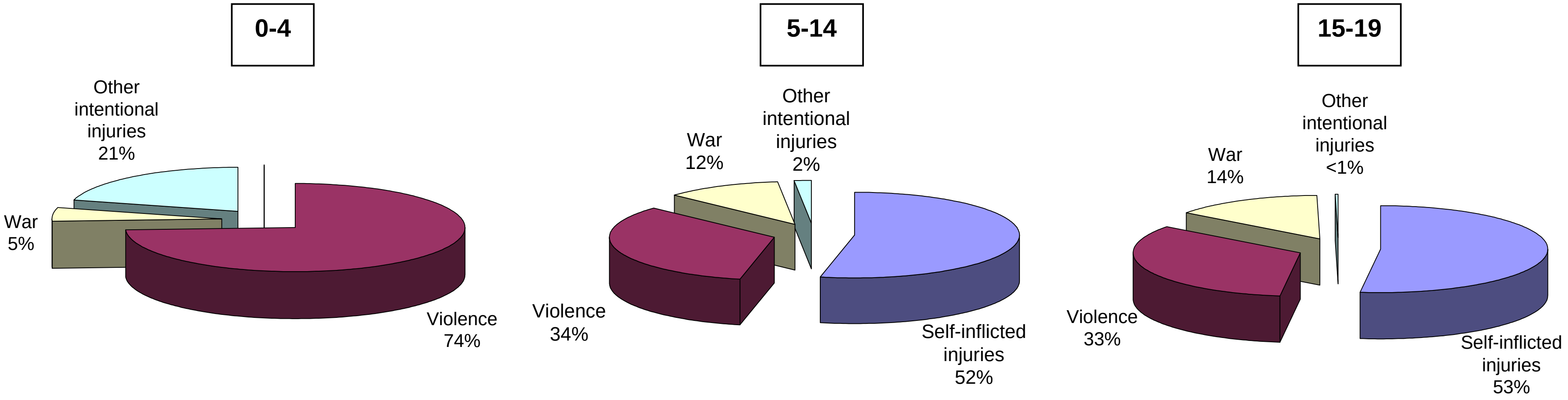


Figure 5.8 Proportion of DALYs for external causes of unintentional injury, by age group, EUR A

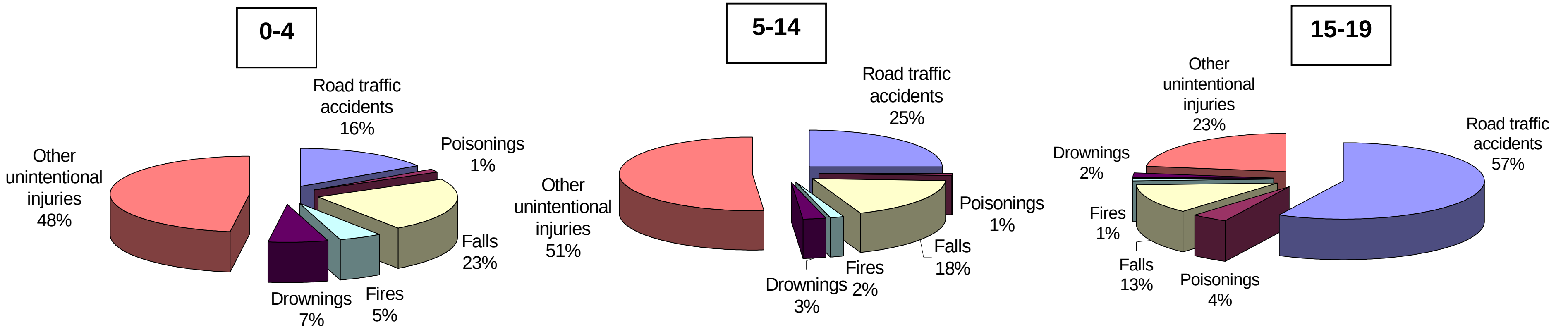


Figure 5.9 Proportion of DALYs for external causes of unintentional injury, by age group, EUR B

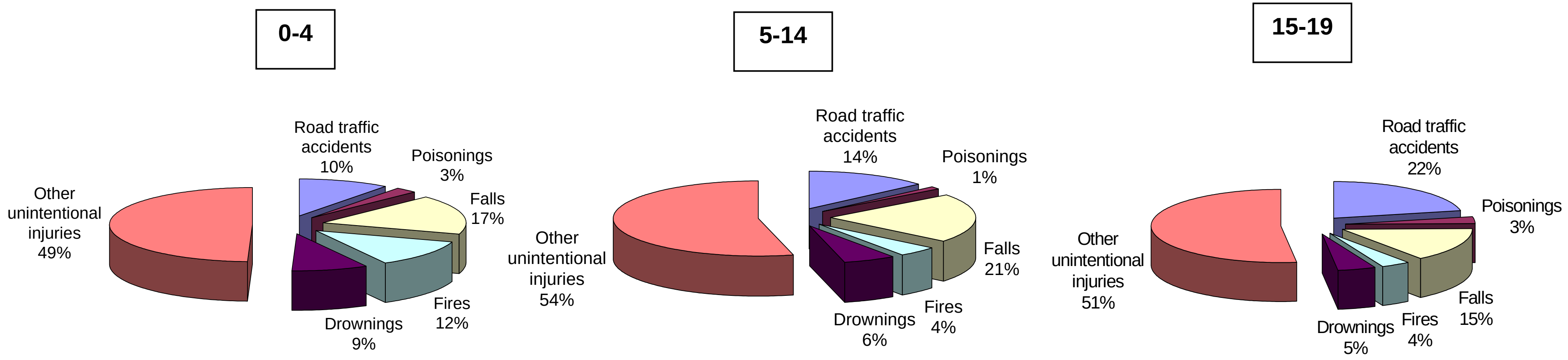


Figure 5.10 Proportion of DALYs for external causes of unintentional injury, by age group, EUR C

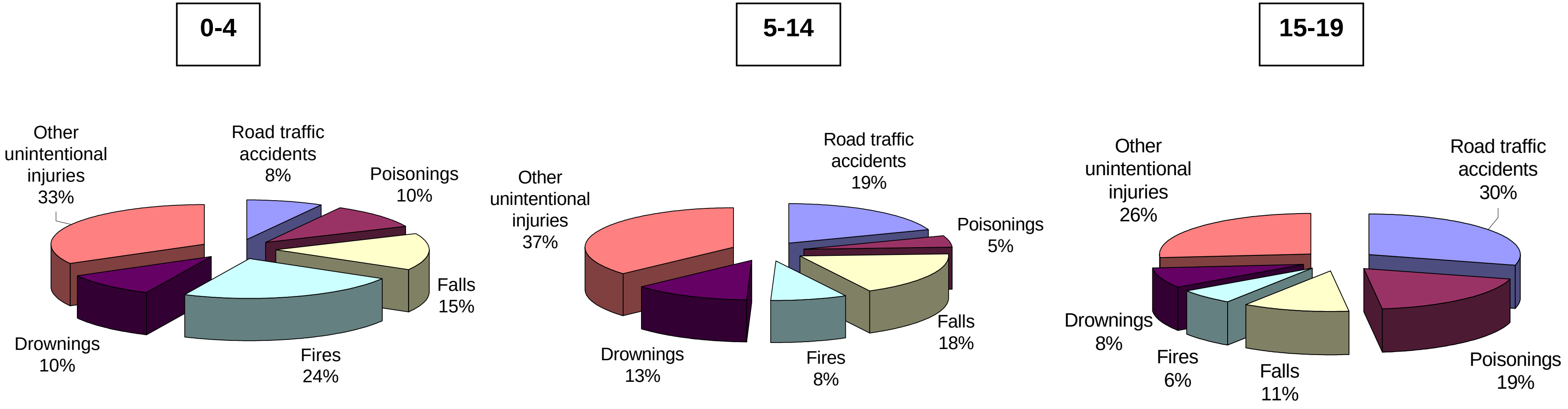


Figure 5.11 Proportion of DALYs for external causes of intentional injury, by age group, EUR A

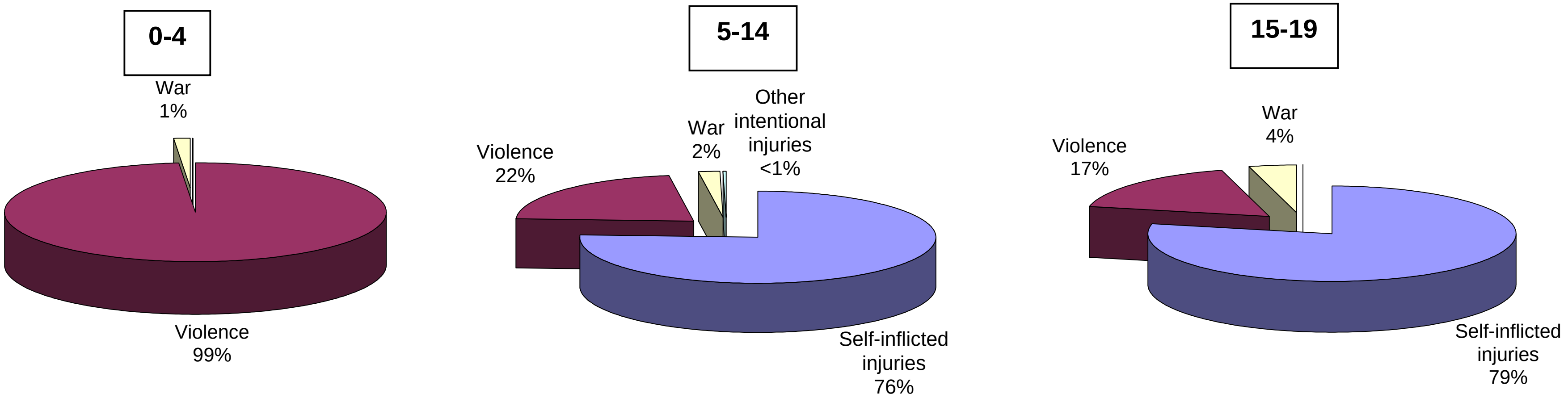


Figure 5.12 Proportion of DALYs for external causes of intentional injury, by age group, EUR B

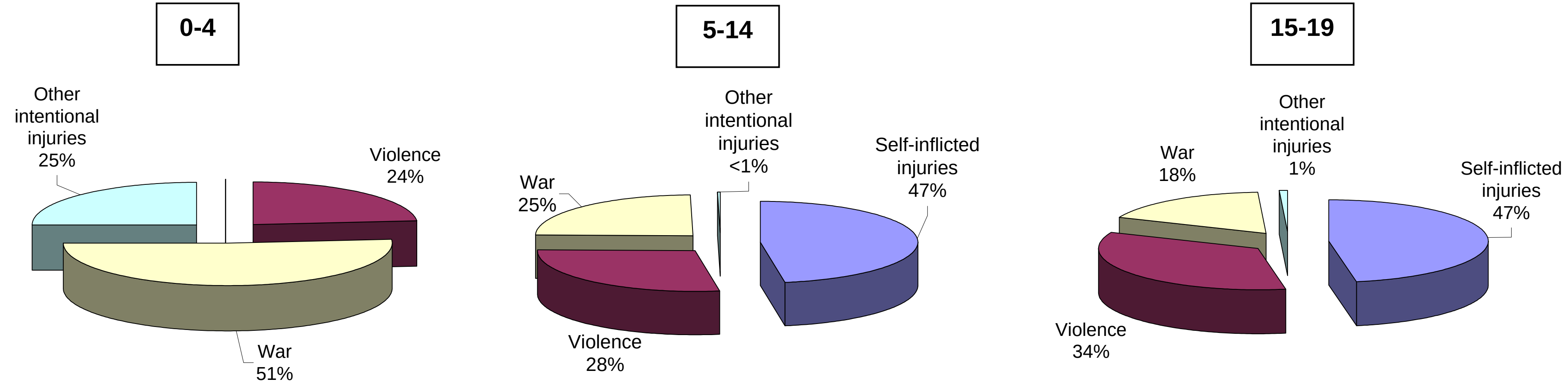
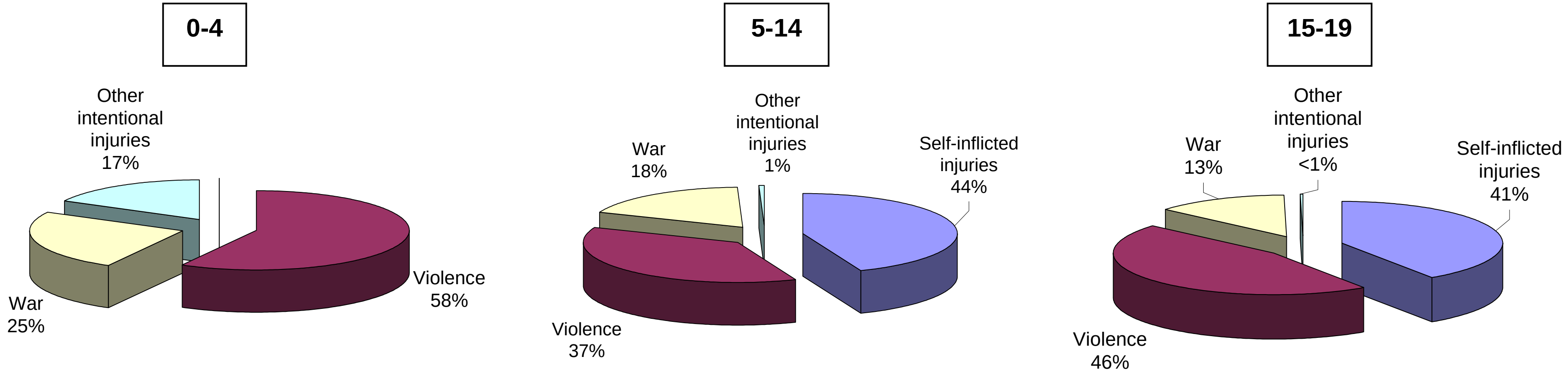


Figure 5.13 Proportion of DALYs for external causes of intentional injury, by age group, EUR C



5.4 Discussion

In Europe, injuries represent 23% of all-cause deaths and 19% of all-cause DALYs among children and adolescents. In EUR C, and particularly EUR A, injuries cause far more deaths and DALYs among children 0–4 years of age than all other environmental factors in the study combined. In EUR B, injuries are relatively less important, but nonetheless they carry heavy health consequences for young children (more than 5 500 deaths and 368 000 DALYs in the age group 0–4 years).

Road traffic accidents are an important cause of injury death and DALYs, particularly in the oldest age group in EUR A. Unfortunately, from the Global Burden of Disease 2001 study (WHO, 2001), it is not possible to break down road traffic accidents to estimate how many deaths and DALYs relate to cars, bicycles, or pedestrians. In fact, national data from some countries show that pedestrian injury deaths in childhood are at least as frequent as car passenger deaths (Roberts, DiGiuseppi & Ward, 1998; Nichilson & Vincenten, 2002).

It is important to recognize that the burden of injury is not only due to road traffic accidents. Among young children in particular, other injury deaths, such as drownings, are almost as frequent as deaths due to road traffic accidents. In EUR C, road traffic accident deaths are outnumbered by fire deaths, drownings and poisonings among children in the 0–4 years age group, and by drownings among those 5−14 years old. Road traffic accidents are an extremely frequent cause of death among adolescents in EUR A, whereas in EUR B and EUR C other causes of death are equally common or more so, even in the oldest age group.

In terms of DALYs, falls appeared to be an important type of injury, particularly in EUR A and EUR B countries, suggesting that falls are likely to produce significant disability in addition to deaths. In EUR C, falls also account for a large number of DALYs, but among children 0–4 years old, fires represent the leading cause of DALYs (almost 30% of injury DALYs). Among those in the 15−19 years age group, almost 20% of injury DALYs are attributable to poisonings. Preventive intervention and regulations should address all types of unintentional injuries, not only road traffic accidents.

In the data presented here, the "other unintentional injuries" represent a large proportion of the burden of injury. In EUR A and B, for example, the proportion of DALYs due to such injuries even exceeded 50% in some age groups. Clearly, a more detailed breakdown of this category of injuries would provide a better understanding of the exact causes of injury deaths and DALYs and facilitate efforts at prevention.

Intentional injuries become extremely frequent as child age increases, representing more than 40% of all injury deaths among adolescents 15−19 years of age in EUR C. Except for the youngest children, for whom death from violence is more frequent, self-inflicted injuries are the most common cause of death from intentional injury in all other age groups. In EUR B and EUR C, deaths due to war are more common among children 5−19 years old than among younger children. In contrast, the burden of DALYs caused by wars in these two subregions is particularly high in the age group 0–4 years, and this is probably due to a greater number of years lived with disability.

5.5 Conclusions

The burden of injuries in children of the European region is primarily due to unintentional injuries, and most are preventable. Policies and services aimed at prevention could therefore reduce the health burden significantly.

6. Summary results

The five environmental exposures and their outcomes, as well as the attributable fractions and burden of disease estimates, are summarized by WHO European subregion and age group in Tables 6.1–6.5. Based on the results of our estimates, approximately 100 000 deaths and 6 million DALYs[1] in the European Region are attributable to the five main environmental risk factors in children. Among children 0–4 years of age, the five risks contributed to 21.9–26.5% of all deaths and to 19.8% of all DALYs. Among those 5–14 years of age, the risk factors contributed to 42.1% of all deaths and to 30.8% of all DALYs. In the 15–19 year age group, they were responsible for 59.9% of all deaths and for 27.1% of all DALYs. The risk factors for the European Region are broken down by age group in Figures 6.1–6.6.

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[1] The total estimate does not include the burden of DALYs due to outdoor air pollution, which was not estimated.

Table 6.1 Burden of disease for outdoor air pollution in children 0–4 years old, by EUR subregion

Subregion	Age group (years)	Outcome	Exposure (%)		Attributable fraction[a] (%)	Attributable deaths		
						Lower estimate	Central estimate	Upper estimate
EUR A	0–4	Deaths from all causes	PM10 ($\mu g/m^3$)	24.84[b]	0.8	37	178	321
				35.96[c]	2.6	120	582	1 040
EUR B				67.01[b]	7.5	2 241	10 617	18 602
				53.86[c]	5.5	1 619	7 730	13 660
EUR C				55.67[b]	5.7	629	3 001	5 298
				61.00[c]	6.6	723	3 435	6 042
EUR A	0–4	Deaths from ARI[d]	PM10 ($\mu g/m^3$)	24.84[b]	0.8	3	1	6
				35.96[c]	2.6	11	2	20
EUR B				67.01[b]	7.5	3 387	715	5 934
				53.86[c]	5.5	2 466	516	4 358
EUR C				55.67[b]	5.7	471	99	831
				61.00[c]	6.6	539	113	948

[a] Defined as the proportion of the outcome attributable to the exposure, using 20 $\mu g/m^3$ as the target PM10 concentration. Only the central estimate is reported.

[b] PM10 estimates from World Bank

[c] PM10 estimates from epidemiological studies

[d] Acute respiratory infections.

Table 6.2 Burden of disease for indoor air pollution in children 0–14 years old, by EUR subregion

Subregion	Age group (years)	Outcome	Exposure (%)		Attributable fraction[a] (%)	Attributable deaths			Attributable DALYs		
						Lower estimate	Central estimate	Upper estimate	Lower estimate	Central estimate	Upper estimate
EUR A	0–4	Acute lower respiratory infections	Population exposed to smoke from solid fuels	0	0	0	0	0	0	0	0
EUR B				20.5	21.0	6 876	9 289	11 409	237 973	321 483	394 837
EUR C				6.4	8.0	394	556	710	13 710	19 335	24 700
EUR A	5–14	Asthma	Population exposed to smoke from solid fuels	0	0	0	0	0	0	0	0
EUR B				20.5	11.0	0	8	16	0	10 164	21 824
EUR C				6.4	4.0	0	1	2	0	1 634	3 870

[a] Defined as the proportion of the outcome attributable to the exposure. Only the central estimate is reported.

Table 6.3 Burden of disease for water, sanitation, and hygiene in children 0–14 years old, by EUR subregion

Subregion	Age group (years)	Outcome	Exposure		Attributable fraction[a] (%)	Attributable deaths			Attributable DALYs		
						Lower estimate	Central estimate	Upper estimate	Lower estimate	Central estimate	Upper estimate
EUR A	0–4	Diarrhoeal disease	% of population in scenarios I–VI[b]	100% in II	60.0	-	60	-	-	20 768	-
EUR B				12% in VI 1% in Vb 8% in Va 79% in IV	87.0	10 201	11 681	12 618	371 828	425 645	459 892
EUR C				1% in VI 5% in Va 94% in IV	86.0	1 322	1 537	1 680	59 918	69 635	76 113
EUR A	5–14	Diarrhoeal disease	% of population in scenarios I–VI	100% in II	60.0	-	3	-	-	5 178	-
EUR B				12% in VI 1% in Vb 8% in Va 79% in IV	87.0	197	172	213	18 449	21 119	22 818
EUR C				1% in VI 5% in Va 94% in IV	86.0	61	71	78	6 536	7 596	8 303

[a] Defined as the proportion of the outcome attributable to the exposure. Only the central estimate is reported.

[b] See Annex 4 for a definition of the scenarios.

Table 6.4 Burden of disease for lead in children 0–4 years old, by EUR subregion[a]

Subregion	Age group (years)	Outcome	Exposure[b]		Attributable DALYs		
					Lower estimate	Central estimate	Upper estimate
EUR A	0–4	Mild mental retardation	BLL[c] (µg/dl)	2.9 (1.5)	1 177	14 092	36 640
EUR B				3.9 (1.6)	25 076	54 711	79 788
EUR C				4.3 (2.4)	87 816	87 816	152 599

[a] The attributable fraction was not calculated because a direct method was used to calculate the burden of disease.

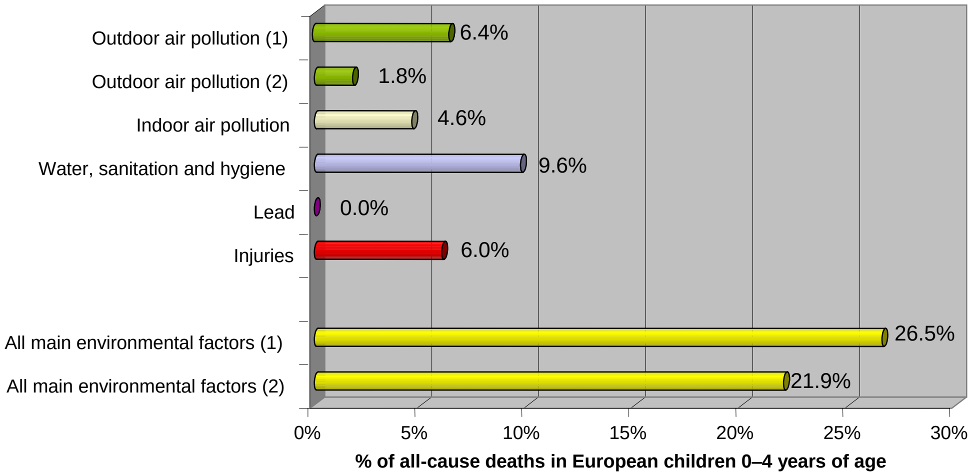
[b] Mean (standard deviation).

[c] BLL = Blood lead levels.

Table 6.5 Burden of disease for all injuries in children 0–19 years old, by EUR subregion

Subregion	Age group (years)	Deaths from injury	DALYs from injury
EUR A	0–4	1 591	128 705
EUR B		5 524	368 149
EUR C		5 759	308 566
EUR A	5–14	2 366	298 916
EUR B		5 087	639 858
EUR C		8 125	732 282
EUR A	15–19	9 492	467 325
EUR B		8 322	520 031
EUR C		28 892	1 329 725

Figure 6.1 Proportion of all-cause deaths attributable to environmental factors among European children 0–4 years of age



(1) Applying relative risk to all-cause deaths for outdoor air pollution.
(2) Applying relative risk t respiratory infections for outdoor air pollution.

Figure 6.2 Proportion of all-cause deaths attributable to environmental factors among European children 5–14 years of age

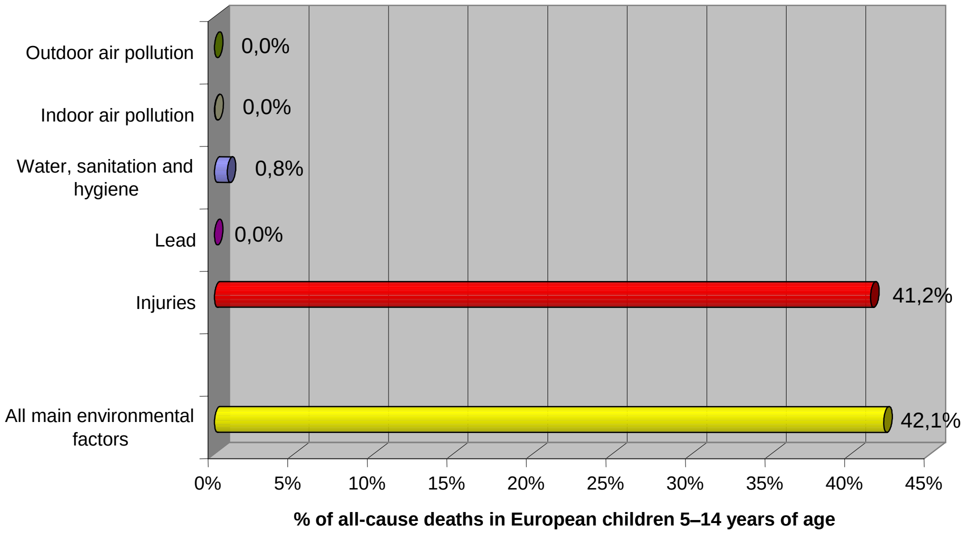


Figure 6.3 Proportion of all-cause deaths attributable to environmental factors among European children 15–19 years of age

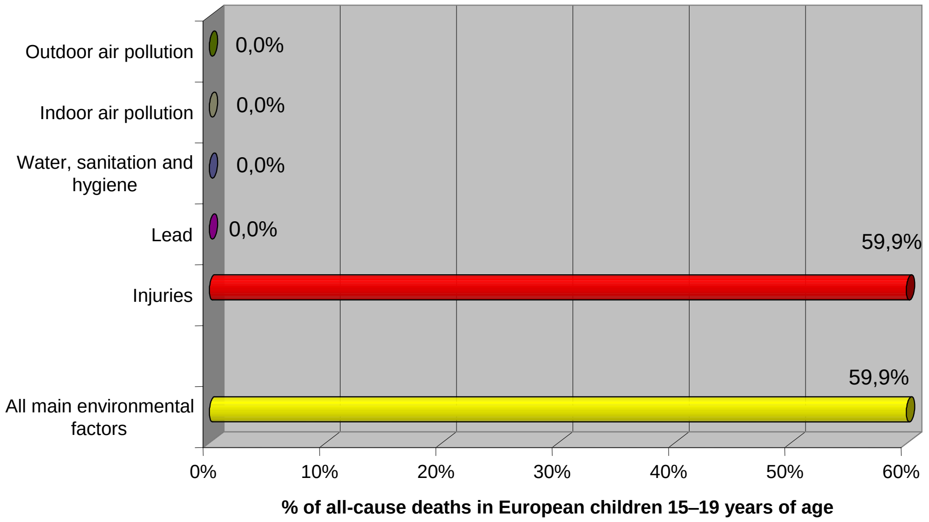


Figure 6.4 Proportion of all-cause DALYs attributable to environmental factors among European children 0–4 years of age

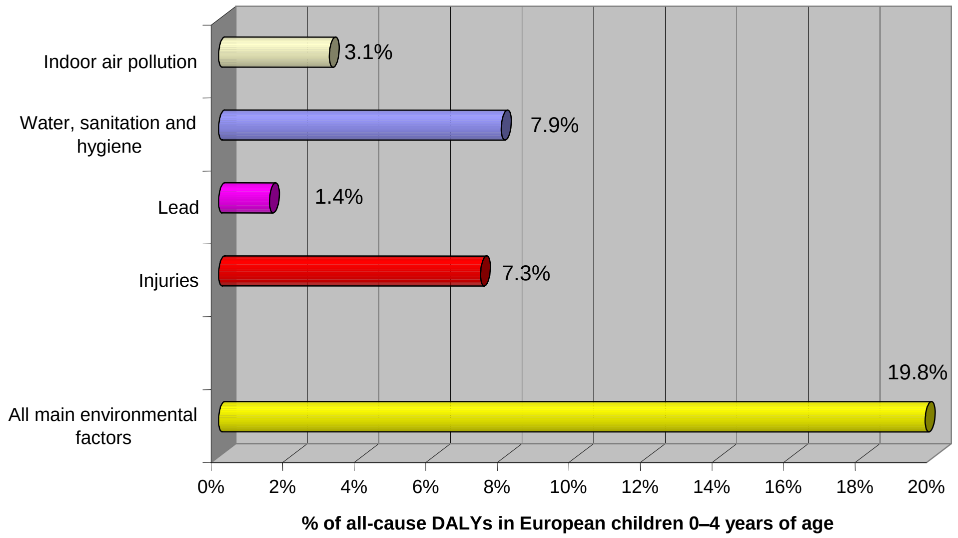


Figure 6.5 Proportion of all-cause DALYs attributable to environmental factors among European children 5–14 years of age

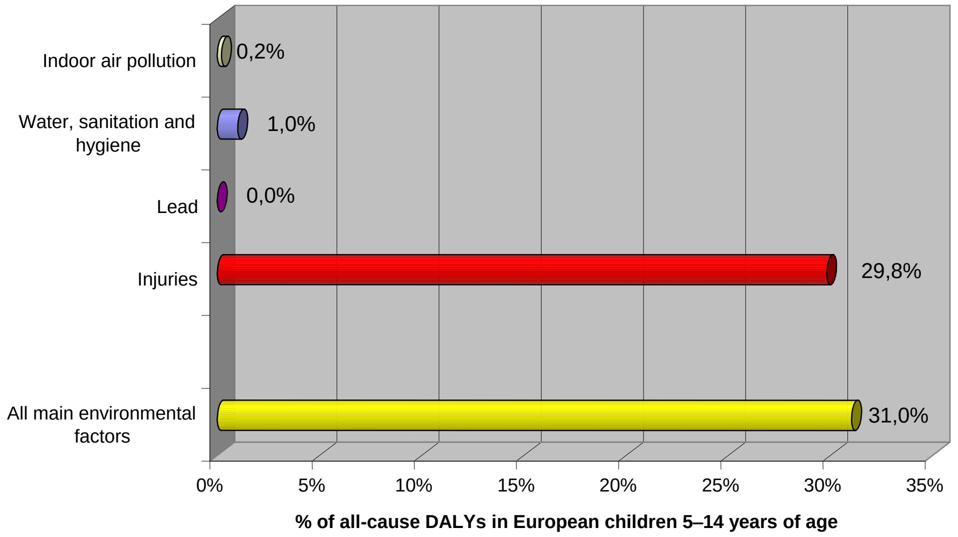
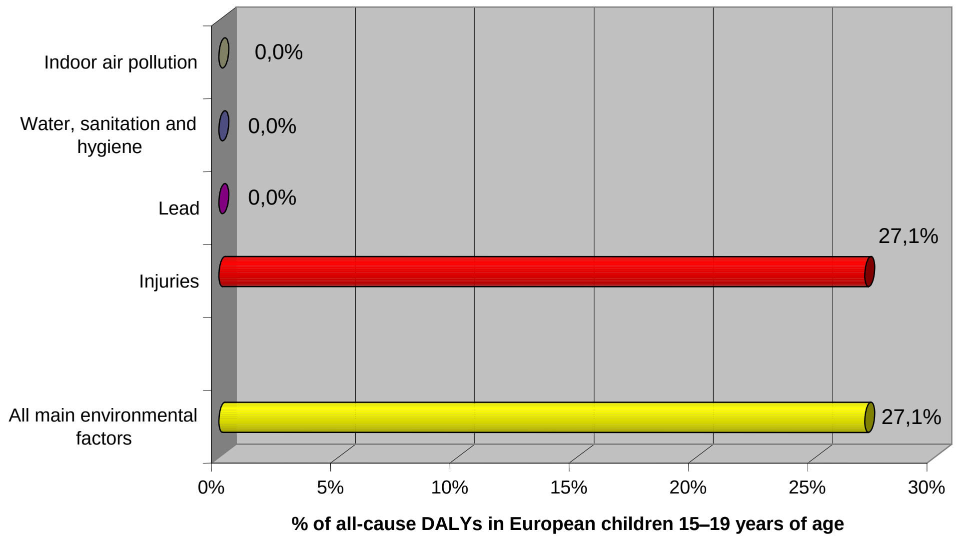


Figure 6.6 Proportion of all-cause DALYs attributable to environmental factors among European children 15–19 years of age



Tables 6.6–6.11 show the deaths and DALYs per 10 000 children that are attributable to the main environmental risk factors, by age group and European subregion. In all subregions, injuries account for the greatest number of deaths and DALYs per 10 000 children for children in the 5–14 and 15–19 year age groups. In contrast, the greatest difference between subregions is in the disease burden for children 0–4 years of age, where factors other than injury are significant. In EUR B, in particular, water, sanitation and hygiene appears to be the most important problem for children 0–4 years old.

Table 6.6 Deaths per 10 000 children 0–4 years of age attributable to five environmental risk factors, for 2001

Risk factor	EUR A	EUR B	EUR C	Totals
Outdoor Air Pollution[a]	0.08	5.91	2.64	2.68
Outdoor Air Pollution[b]	0	1.88	0.42	0.74
Indoor Air Pollution	0	5.17	0.49	1.91
Water Sanitation and Hygiene	0.03	9.79	2.72	4.02
Lead[c]	0	0	0	0
Injuries	0.72	3.07	5.07	2.50
Totals[a]	0.82	23.94	10.93	11.11
Totals[b]	0.74	19.98	8.70	9.20

[a] Considering all-cause deaths as the outcome for outdoor air pollution.

[b] Considering deaths from acute lower respiratory infection as the outcome for outdoor air pollution.

[c] Deaths attributable to lead were not estimated.

Table 6.7 Deaths per 10 000 children 5–14 years of age attributable to five environmental risk factors, for 2001

Risk factor	EUR A	EUR B	EUR C	Totals
Outdoor Air Pollution	0	0	0	0
Indoor Air Pollution	0	0	0	0
Water Sanitation and Hygiene	0	0.04	0.04	0.02
Lead[a]	0	0	0	0
Injuries	0.50	1.24	2.39	1.27
Totals	0.50	1.28	2.43	1.29

[a] Deaths attributable to lead were not estimated.

Table 6.8 Deaths per 10 000 children 15–19 years of age attributable to five environmental risk factors, for 2001

Risk factor	EUR A	EUR B	EUR C	Totals
Outdoor Air Pollution	0	0	0	0
Indoor Air Pollution	0	0	0	0
Water Sanitation and Hygiene	0	0	0	0
Lead[a]	0	0	0	0
Injuries	3.78	4.08	14.80	7.19
Totals	3.78	4.08	14.80	7.19

[a] Deaths attributable to lead were not estimated.

Table 6.9 DALYs per 10 000 children 0–4 years of age attributable to four[a] environmental risk factors, for 2001

Risk factor	EUR A	EUR B	EUR C	Totals
Indoor Air Pollution	0	178.90	17.04	66.16
Water Sanitation and Hygiene	10.58	386.09	134.03	168.70
Lead	6.34	30.45	77.38	30.39
Injuries	57.93	204.87	271.91	156.28
Totals	74.85	800.30	500.30	421.50

[a] DALYs attributable to outdoor air pollution were not calculated.

Table 6.10 DALYs per 10 000 children 5–14 years of age attributable to four[a] environmental risk factors, 2001.

Risk factor	EUR A	EUR B	EUR C	Totals
Indoor Air Pollution	0	2.47	0.48	0.96
Water Sanitation and Hygiene	1.28	6.77	6.60	4.59
Lead	0	0	0	0
Injuries	62.68	155.64	215.63	136.10
Totals	63.95	164.89	222.63	141.66

[a] DALYs attributable to outdoor air pollution were not calculated.

Table 6.11 DALYs per 10 000 children 15–19 years of age attributable to four[a] environmental risk factors, for 2001

Risk factor	EUR A	EUR B	EUR C	Totals
Indoor Air Pollution	0	0	0	0
Water Sanitation and Hygiene	0	0	0	0
Lead	0	0	0	0
Injuries	186.31	255.09	681.04	356.51
Totals	186.31	255.09	681.04	356.51

[a] DALYs attributable to outdoor air pollution were not calculated.

7. Uncertainties

The aim of burden of disease studies is to quantify risk factors to health in a comparative and internally consistent way. This would provide a framework for policy-makers and the public to assess the impact of disease on the population. It would also serve as a basis for setting priorities and, when combined with cost−effectiveness analysis, would better allocate scarce health resources. Although everyone is affected by environmental risks to some degree, the poor and children bear a disproportionate burden. The aim of this study was to quantify the environmental risks to health in one of the most affected groups – children.

Assessing the EBD is a complex process because the determinants and etiological pathways of the disease process, as well as the setting in which these risks occur, must be considered. The political, economic and social systems of a country largely determine the exposures and risks to the population. If health-based criteria are used to classify countries and subregions, the resulting classification may not correspond well with the distribution of environmental risks. This may be the case for the European Region. The WHO classification of subregions is based on adult and child mortality (see Annex 1), and may not reflect differences in the health, economic and political structures that are important in determining the extent to which children are affected by the environment. For example, Central Asian Republics, which are similar in many ways, are split into EUR B and EUR C subregions (Annex 1). A classification based on child mortality alone would have been more valid for the purpose of his study, and corresponded better to the actual socioeconomic and environmental context.

One consequence of the classification scheme we adopted is that EUR A is the only subregion for which subregional estimates can reasonably be applied to single countries in the subregion. A second consequence is that there are no great differences in the estimates for EUR B and EUR C. It may be that if a classification based on infant and child mortality had been adopted (e.g. very low, low, and intermediate infant and child mortality), there would have been a clearer gradient in the EBD. Therefore, the differences between EUR B and EUR C should be interpreted conservatively.

The results also have been biased by the weighting for the child population of a country, in favour of those countries with the highest rates of child mortality and absolute numbers of children. For example, in EUR B, Turkey has one of the highest child mortality rates and absolute numbers of children. The results may also be skewed by the availability of data, which came primarily from countries of EUR A. In addition, since much of the literature on exposure−risk relationships comes from countries outside of the European Region (i.e. in developing countries), many relationships had to be extrapolated to fit the European context. However, these extrapolations may not always be accurate. We found that changing exposure estimates by even a small amount had a significant impact upon estimates of deaths and DALYs, which underlines the importance of using the most accurate exposure data available. This clearly indicates the need for better data to improve burden of disease estimates.

Finally, our analyses for the three risk factors: indoor air pollution; water, sanitation and hygiene; and injuries used estimates from the WHO Global Burden of Disease 2001 study. The validity of the results for these factors therefore depends on the validity of the WHO estimates.

8. Conclusions

This study represents the first attempt to assess the impact of environmental risk factors on child health in the WHO European Region. A motivation for the study was the dearth of information in this area, as a result of which our understanding of how the environment affects the health of children, either directly or via adults during the reproductive years, is still incomplete. Action in this area is all the more urgent, since interventions to reduce exposure to environmental risk factors and to prevent injuries can result in substantial public-health gains. For example, phasing out lead from gasoline is effective in reducing environmental and population BLL (Smith, Corvalan & Kjellstrom, 1999; WHO, 2000a, 2002; WHO-CHOICE, 2003). Multisectoral approaches, such as engineering, educational and law enforcement interventions, also reduce the incidence of injury and the severity of the consequences (Bobak & Leon, 1992; World Bank, 2003a).

The results of our study show that air pollution, unsafe water, lead and injuries account for a high proportion of the burden of disease and deaths from all causes in children. The results also show that children are not uniformly exposed to environmental risk factors in the three EUR subregions. The variation is due to a combination of poor housing conditions, a polluted environment, and restricted access to information, preventive programmes and health care.

The findings indicate there is an urgent need for a plan of action that specifically addresses priorities for the environmental health of children. A plan of action should take into account the marked differences in the EBD for each risk factor by subregion and age group, which underscores the need for targeted action.

We hope the results of this study will serve as a foundation for further EBD studies in the European Region, and stimulate countries to initiate their own studies. When implementing national burden of disease studies, it is important to standardize how morbidity and mortality statistics are collected at the subregional level. This is especially important for EUR B and EUR C, where few data are available. The present study could also be a starting point for cost–benefit analyses of interventions to reduce the EBD.

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Annex 1 Member States of the WHO European mortality subregions

The 191 WHO Member States have been classified into five mortality strata on the basis of their levels of child mortality (under 5 years of age) and adult mortality (males 15–59 years old), using population estimates for 1999 (UNPD, 1999). Quintiles of the distribution of child mortality (both sexes combined) were used to define a very low child mortality group (1st quintile), a low child mortality group (2nd and 3rd quintiles), and a high child mortality group (4th and 5th quintiles). Adult mortality was regressed on child mortality, and the regression line used to divide countries with high child mortality into high adult mortality (stratum D) and very high adult mortality (stratum E) (WHO-CHOICE, 2003). According to this division, there are three subregions in Europe: EUR A, with very low child, very low adult mortality; EUR B, with low child, low adult mortality; and EUR C, with low child, high adult mortality. Member States included in each subregion are listed in Table A1.1 and shown on a world map (Figure A1.1). The population sizes and mortality rates for infants and children in the Member States are shown in Table A1.2.

Table A1.1 Member States of the three EUR subregions[1]

EUR A (very low child, very low adult mortality)	EUR B (low child, low adult mortality)	EUR C (low child, high adult mortality)
ANDORRA	ALBANIA	BELARUS
AUSTRIA	ARMENIA	ESTONIA
BELGIUM	AZERBAIJAN	HUNGARY
CROATIA	BOSNIA AND HERZEGOVINA	KAZAKHSTAN
CZECH REPUBLIC	BULGARIA	LATVIA
DENMARK	GEORGIA	LITHUANIA
FINLAND	KYRGYZSTAN	REPUBLIC OF MOLDOVA
FRANCE	POLAND	RUSSIAN FEDERATION
GERMANY	ROMANIA	UKRAINE
GREECE	SERBIA AND MONTENEGRO	
ICELAND	SLOVAKIA	
IRELAND	TAJIKISTAN	
ISRAEL	THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA	
ITALY	TURKEY	
LUXEMBOURG	TURKMENISTAN	
MALTA	UZBEKISTAN	
MONACO		
NETHERLANDS		
NORWAY		
PORTUGAL		
SAN MARINO		
SLOVENIA		
SPAIN		
SWEDEN		
SWITZERLAND		
UNITED KINGDOM		

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[1] At the time the study was carried out Cyprus was not part of the WHO European Region. For this reason, data from this country was not included in this analysis. World health assembly: (2003): 18-28 May 2003 A56/37 Reassignment of Cyprus from the Eastern Mediterranean Region to the European Region: http://www.who.int/gb/ebwha/pdf_files/WHA56/ea5637.pdf

Figure A1.1 WHO European subregions

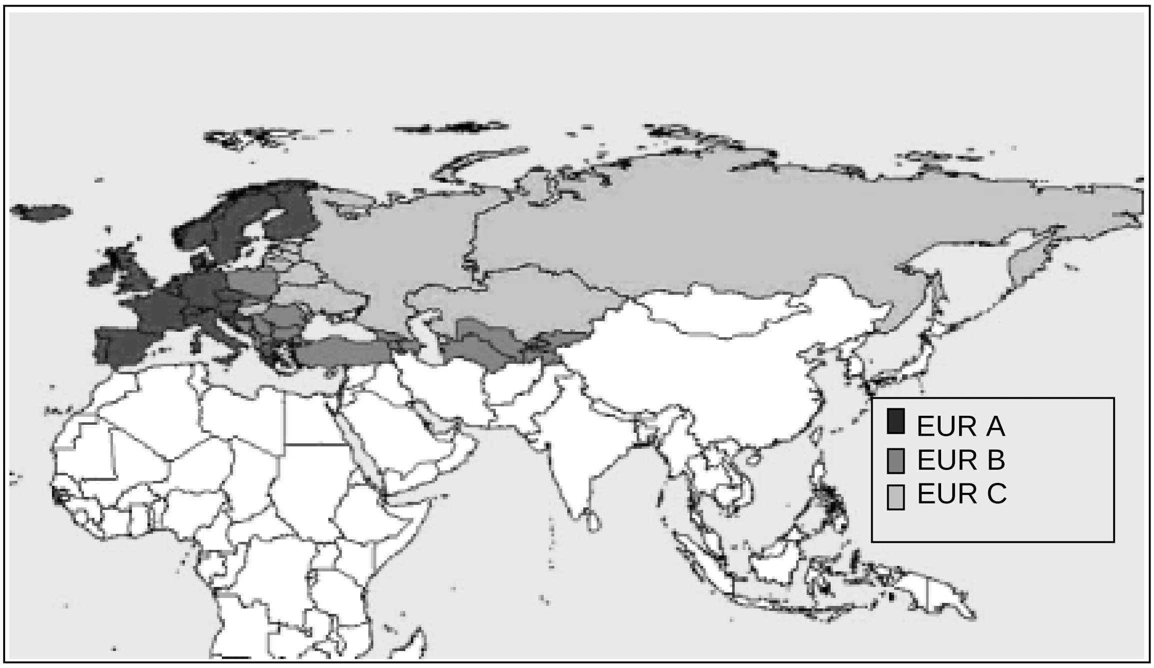

Table A1.2 Population size and mortality rates in infants and children for Member States of the WHO European subregions[a]

Country	Population 0–4 years old (thousands)	Population 0–19 years old (thousands)	Infant mortality (Per 1 000 births)	Mortality in children younger than 5 years (per 1 000 births)
EUR A				
Andorra	N/A[b]	N/A	N/A	N/A
Austria	409	1 833	4.7	6
Belgium	568	2 396	4.2	6
Croatia	239	1 069	8.1	9
Czech Republic	452	2 379	5.6	6
Denmark	330	1 249	5.0	6
Finland	295	1 269	4.0	5
France	3 692	1 5067	5.0	6
Germany	3 930	17 529	4.5	6
Greece	516	2 355	6.4	8
Iceland	21	87	3.4	4
Ireland	263	1 164	5.8	7
Israel	615	2 232	5.9	9
Italy	2 627	11 276	5.4	7
Luxembourg	28	107	5.4	7
Malta	24	107	7.1	8
Monaco	N/A	N/A	N/A	N/A
Netherlands	971	3 851	4.5	6
Norway	293	1 149	4.5	6
Portugal	561	2 334	6.1	8
San Marino	N/A	N/A	N/A	N/A
Slovenia	91	457	5.5	7
Spain	1 927	8 565	5.1	7
Sweden	454	2 125	3.4	4
Switzerland	368	1 589	4.8	6
United Kingdom	3 544	14 812	5.4	7
EUR B				
Albania	288	1 199	25.0	34
Armenia	167	1 041	17.3	20
Azerbaijan	714	3 366	29.3	40
Bosnia Herzeg.	205	1 064	13.5	16
Bulgaria	323	1 834	15.2	19
Georgia	299	1 497	17.6	22
Kyrgyzstan	542	2 181	37.0	46
Poland	2 026	10 798	9.1	11
Romania	1 142	5 762	20.0	25
Serbia Monten.	642	2 931	13.0	15
Slovakia	288	1 499	8.0	10
Tajikistan	775	3 064	50.0	73
Macedonia	144	624	16.0	18
Turkey	7 132	28 561	39.5	49
Turkmenistan	508	2 182	48.6	68
Uzbekistan	2 793	11 762	36.7	52
EUR C				
Belarus	436	2 689	11.3	15
Estonia	60	350	9.4	11
Hungary	495	2 345	8.8	11
Kazakhstan	1 193	5 774	51.7	58
Latvia	97	605	14.2	18
Lithuania	186	966	8.7	11
Moldova	250	1 383	18.1	24
Russian Fed.	6 445	38 110	15.9	22
Ukraine	2 186	12 625	13.8	18

[a] Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2002 Revision and World Urbanization Prospects: The 2001 Revision. Available at: http://esa.un.org/unpp. Accessed 5 September 2003.

[b] N/A: data not available.

Annex 2 Strength of evidence for the association between solid-fuel use and health outcomes

The health outcomes assessed in this study were selected on the basis of the strength of the evidence associating SFU with outcome (Smith et al., 2003). Evidence from the epidemiological literature was ranked as strong, moderate, or insufficient, according to the Hill Criteria (Desai, Mehta & Smith, 2003):

- *Strong evidence* indicates that developing country household studies reveal a consistent, sizeable, plausible, and coherent relationship with supporting evidence from studies of outdoor air pollution, active and passive smoking, and laboratory animals.
- *Moderate evidence* indicates a relatively small number of suggestive findings from developing country household studies, and some evidence from studies on outdoor air pollution, smoking, and laboratory animals. Additional studies are needed to strengthen the evidence. Moderate evidence can be further subdivided into:
  - *Moderate-I*, when the evidence associating SFU with a health endpoint is strong for a specific age group or sex.
  - *Moderate-II*, when there is no strong evidence associating SFU with a health endpoint
- *Insufficient evidence* indicates that the evidence for an association between SFU and the health endpoint does not meet the criteria to be included in the Strong or Moderate categories. For example, the evidence for adverse pregnancy as a health outcome falls into this category.

For diseases that affect children, the only health outcomes with Strong or Moderate evidence were ALRI in children younger than 5 years of age (strong evidence), and asthma in children 5−14 years of age (Moderate-II evidence).

Annex 3 Exposure data for household use of solid fuels

Household SFU estimates[1] for countries in the WHO European Region are shown in Table A3.1. Countries listed in normal font indicate that the country estimates are based on extrapolations from fuel use surveys. For these countries, low and high estimates are based on an arbitrary +/- 5% uncertainty range. Countries listed in bold font indicate the estimates are based on the statistical model used in the Global Burden of Disease study. For these countries, low and high estimates are the 95% confidence intervals generated by the model.

Table A3.1 Household solid-fuel use for countries in the WHO European Region

				Accounting for ventilation		
Subregion	**Country**	**Household SFU (%)**	**Ventilation coefficient[a]**	**Central estimate (%)**	**Low estimate (%)**	**High estimate (%)**
EUR A	**Croatia**	15	0.2	3	0	8
EUR A	**Israel**	0	1.0	0	0	30
EUR A	Austria	0	1.0	0	0	0
EUR A	Belgium	0	1.0	0	0	0
EUR A	Czech Republic	0	0.2	0	0	0
EUR A	Denmark	0	1.0	0	0	0
EUR A	Finland	0	1.0	0	0	0
EUR A	France (inc. Monaco)	0	1.0	0	0	0
EUR A	Germany	0	1.0	0	0	0
EUR A	Greece	0	1.0	0	0	0
EUR A	Ireland	0	1.0	0	0	0
EUR A	Italy (inc. San Marino)	0	1.0	0	0	0
EUR A	Netherlands	0	1.0	0	0	0
EUR A	Norway	0	1.0	0	0	0
EUR A	Portugal	0	1.0	0	0	0
EUR A	Slovenia	0	0.2	0	0	0
EUR A	Spain	0	1.0	0	0	0
EUR A	Sweden	0	1.0	0	0	0
EUR A	Switzerland (inc. Liecht.)	0	1.0	0	0	0
EUR A	United Kingdom	0	1.0	0	0	0
EUR B	**Albania**	76	0.2	15	14	17
EUR B	**Bosnia and Herzegovina**	74	0.2	15	14	16
EUR B	**Bulgaria**	31	0.2	6	3	9
EUR B	**Armenia**	66	1.0	66	49	83
EUR B	**Azerbaijan**	37	1.0	37	15	59
EUR B	**Georgia**	71	1.0	71	58	84
EUR B	**Kyrgyzstan**	96	1.0	96	87	100
EUR B	**Macedonia**	58	0.2	12	9	14
EUR B	**Poland**	37	0.2	7	5	10
EUR B	**Romania**	45	0.2	9	7	11

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[1] WHO Department of Protection of the Human Environment. Information presented at the *Workshop on Environmental Burden of Disease: Expert network and methods*. Geneva, 17–19 March 2003.

				Accounting for ventilation		
Subregion	**Country**	**Household SFU (%)**	**Ventilation coefficient**[a]	**Central estimate (%)**	**Low estimate (%)**	**High estimate (%)**
EUR B	**Slovakia**	24	0.2	5	1	8
EUR B	**Tajikistan**	100	1.0	100	93	100
EUR B	Turkey	11	1.0	11	6	16
EUR B	**Turkmenistan**	50	1.0	50	33	68
EUR B	**Uzbekistan**	79	1.0	79	72	85
EUR B	**Yugoslavia**	69	0.2	14	12	15
EUR C	**Belarus**	10	0.2	2	0	6
EUR C	**Estonia**	39	0.2	8	5	11
EUR C	**Hungary**	26	0.2	5	2	8
EUR C	**Kazakhstan**	51	1.0	51	42	59
EUR C	**Latvia**	19	0.2	4	0	7
EUR C	**Lithuania**	42	0.2	8	6	11
EUR C	**Moldova**	72	0.2	14	13	16
EUR C	**Russian Federation**	7	0.2	1	0	6
EUR C	**Ukraine**	56	0.2	11	9	14

[a] The ventilation coefficient accounts for the ventilation in households and should be based on expert opinion. For example, SFU outdoors results in complete ventilation and has a ventilation coefficient of 0; an improved stove programme could result in ventilation coefficient of 0.25; and a poorly ventilated household would have a coefficient of 1.0.

Annex 4 Definition of scenarios and relative risks for water, sanitation and hygiene

Table A4.1 Definition of scenarios for improved water, sanitation and hygiene services[a]

Scenario	Definition
VI	No improved water supply and no basic sanitation in a country that is not extensively covered by such services, and where water supply is not routinely controlled.
Vb	Improved water supply and no basic sanitation in a country that is not extensively covered by such services, and where water supply is not routinely controlled.
Va	Basic sanitation, but no improved water supply in a country that is not extensively covered by such services, and where water supply is not routinely controlled.
IV	Improved water supply and basic sanitation in a country that is not extensively covered by such services, and where water supply is not routinely controlled.
IIIc	IV and improved access/quality to drinking-water (generally piped to household).
IIIb	IV and improved personal hygiene.
IIIa	IV and drinking-water disinfected at point of use.
II	Regulated water supply and full sanitation coverage, with partial treatment for sewage, corresponding to a situation typically occurring in developed countries.
I	Ideal situation, no transmission of diarrhoeal disease through water, sanitation or hygiene.

[a] Source: Průss et al. (2002).

Table A4.2 Relative risks for water, sanitation and hygiene scenarios[a]

	I	II	IV	Va	Vb	VI
Low estimate	1	2.5	3.85	3.85	4.85	6.1
Best estimate	1	2.5	6.9	6.9	8.7	11.0
High estimate	1	2.5	15.5	15.5	19.5	24.8

[a] Source: Tools and information. Presented at the *Workshop on Environmental Burden of Disease: Expert network and methods*. Geneva, 17-19 March 2003.

Annex 5 Discounting and age weighting

Discounting and age weighting account for choices in social values when estimating the burden of disease. Time discounting accounts for the social preference to discount health in the future (i.e. one healthy year of life in the present is valued more than one healthy year of life in the future). In the Global Burden of Disease study (Murray & Lopez, 1996), a 3% time discount rate to years of life lost in the future was used to estimate the present net value of years of life lost. The Global Burden of Disease study also weighted a year of healthy life lived at young ages and older ages lower than for other ages. This choice is based again on the social preference to value a year lived by a young adult more than a year lived by an infant or older person. The need to account for such social preference led to the incorporation of age weighting when calculating DALYs.

Global Burden of Disease 2001 estimates of non-age-weighted DALYs, with and without discounting, are available at the WHO web site:
(http://www3.who.int/whosis/menu.cfm?path=whosis,burden,burden_estimates,burden_estimates_2001,burden_estimates_2001_region&language=english).
However, discounted and age-weighted DALYs are the WHO standard. For more information on DALYs and social value choices see Murray & Acharya (1997).