Methodological annex: Estimation of health impacts of ambient air pollution and improvements associated with interventions

Exposure to high levels of pollutants in the air that the population is exposed to leads to significant health impacts. Estimations of these impacts at the national level are regularly made by the European Environmental Agency and published in the Air Quality in Europe Study[1]. This report takes these estimates to the regional level and the Slovak context and adds also the maximum exposure level recommended by the World Health Organisation to compare with the current exposure. Economic value is then calculated for each of the health impacts.

The estimates of policy costs of reducing emissions of harmful pollutants are compared against their benefits in terms of reduced health damages. The net benefits are reported using the ratio of the present value of benefits to the present value of cost. The project thus broadens the knowledge base for future decision making on issues dealing with transition towards sustainable energy resources as well as the policy considerations for major polluting sources.

Air quality and health data

Levels of exposure to ambient air pollution have been made for each of the districts in Slovakia (cities of Bratislava and Košice are counted as one district each). The concentration levels in each district have been weighted by the population exposed to the certain level of pollution. The calculations have been made by the Slovak Hydrometeorological Institute for concentrations of these pollutants:

- $PM_{2.5}$, Annual Mean
- $PM_{2.5}$, Daily Mean
- PM_{10}, Annual Mean
- PM_{10}, Daily Mean
- NO_2, Annual Mean
- NO_2, Maximum 1-Hour

Significant impacts have, however, been observed only in the case of $PM_{2.5}$, PM_{10} and NO_2 annual Mean (they can be found in the toolbox input sheet IN_YearPol).

While shorter exposure levels certainly have impacts as well, averaging at the district scale used in this study makes these impacts hard to determine. More local observation could detect specific health impacts in certain locations with higher short-term exposure. Estimation of effects of a full implementation of the National Air Pollution Control Programme have been made for each district and each pollutant by the Slovak Hydrometeorological Institute (also found in the toolbox input sheet In_YearPol). All the air quality data have been calculated using advanced modelling and include an upper and lower bound interval.

The health data related to baseline mortality in each of the studied age groups at the district level have been provided by the National Health Information Centre and the population data has been collected from the public sources of the Statistical office of the Slovak republic. They are found in the calculation sheets for each of the health impacts.

Estimation of health impacts

The relative risk shows the ratio of risks or probabilities of an adverse health event among the exposed and non-exposed group[2]. The relative risk in the table describes how much the morbidity or mortality would increase if the

[1] https://www.eea.europa.eu/publications/air-quality-in-europe-2020-report
[2] In the epidemiological literature the relative risk is sometimes related to a concept called the Population Attributable Fraction (PAF). PAF is the proportional increase in population disease or mortality that would occur if exposure to a risk factor were

pollution level increased by 10µg/m³. The 95% CI shows the range of relative risk and our estimates that lie within a 95% confidence interval. Different pollutants are linked to different health outcomes based on information from a wide range of epidemiological studies.

Dose Response Functions Used in Making Estimates of Health Impacts

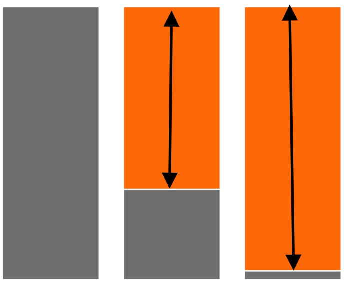
Pollutant Metric	Health Outcome	RR (95% CI) per 10µg/m³	Guideline Value for Estimation
$PM_{2.5}$ Annual Average	All-Cause Mortality. Age 30+	1.062 (1.040 – 1.083)	10 µg/m³
$PM_{2.5}$ Annual Average	Restricted Activity Days. All Ages	1.047 (1.042 – 1.053)	10 µg/m³
$PM_{2.5}$ Annual Average	Work Days Lost. Ages 20-65	1.046 (1.039 – 1.053)	10 µg/m³
PM_{10} Annual Average	All-Cause Post Neonatal Mortality 1-12 Months	1.04 (1.02 – 1.07)	20 µg/m³
PM_{10} Annual Average	Incidence of Chronic Bronchitis Age 18+	1.117 (1.040 – 1.189)	20 µg/m³
PM_{10} Daily Mean	Asthma Events. Ages 5-19	1.028 (1.006 – 1.051)	20 µg/m³

Source: WHO (2013)

The data provided above have been estimated by the WHO for the European context. It could be substituted with local information and re-estimated to produce a local RR function for Slovakia. That would require a series of epidemiological studies to estimate more localised information.

Calculations using the dose response functions estimating the physical impacts of air pollution can be found in the toolbox on individual sheets for each of the health indicators (All-cause mortality, neonatal mortality, restricted activity days, work days lost and chronic bronchitis in adults). Three scenarios are included in each sheet – baseline scenario (using 2017 data) and projections for the year 2020 and 2030. Ranges are calculated to account for uncertainties in the air quality data as well as in the relative risk.

Summary sheet (Mean reductions) summarizes all health impacts and allows the user to switch between different guideline values. Maximum exposure level set by the WHO is used in the study as a baseline, since it describes what proportion of health impacts could be avoided by reaching the level recommended. Stricter no-pollution guideline values (used by the EEA in the 'Air Quality in Europe' reports) can also be selected to calculate the total impacts of air pollution on health. However, such a reference value is unrealistic since concentrations of pollutants in the ambient air are unlikely to decline to zero. The last studied guideline value is set by the EU Directive 2008/50/EC, but due to averaging at the district level, all the current values fall below this guideline. The impacts of air pollution are estimated as the difference between modelled air pollution level and baseline level. The chart on the right shows the total calculated air pollution impacts in orange.



increased from an alternative ideal exposure scenario: Mathematically it is expressed as: $PAF = \frac{(P_i - P_i^{'})RR}{P_i RR}$ where Pi=proportion of population at exposure level i, current exposure and $P_i^{'}$= proportion of population at exposure level i, counterfactual or ideal level of exposure. See: WHO | Metrics: Population Attributable Fraction (PAF)

Three sets of guideline values used (in µg/m[3])

	PM2,5 - yearly	PM2,5 - daily	PM10 - yearly	PM10 - daily	NO2 - yearly	NO2 - max/hour
EEA	0	0	0	0	20	0
WHO	10	25	20	50	40	200
EU directive[3]	20	25	40	50	40	200

Economic valuations of health effects

The valuation of health impacts is divided into the valuation of premature mortality and the valuation of different morbidity endpoints. For premature mortality the literature values such cases using either the "Value of a Statistical Life" (VSL) or the "Value of Life Years Lost" (VLYL or also called VOLY). The value of statistical life is a measure based on how much individuals would be willing to pay to reduce their risk of death. For example, if a group of 100,000 individuals is willing to pay €10 each for a measure that reduces their risk of death by 1:100,000, , the group would pay a total amount of €1 million (i.e. 10x100,000) to save one life. The total amount of one million is called the VSL because it represents the amount people are willing to pay to save one non-specific (i.e. statistical) life. The VLYL is based on a similar argument but now the valuation is for a measure that reduces the risk of losing one year of life.[4]

Recent research on the value of life in the EU28 estimates the VSL at €3,370,891 (mean), with a range of €1,685,446 (low) and €5,056,337 (high)[5]. These values are in 2011 prices. Adjusting for inflation to convert them into 2019 prices gives the following values: €3,668,844 (mean), €1,834,423 (low) and €5,503,267 (High)[6]. These values apply for the whole of the EU28. As the GDP per capita in Slovakia is below the average of the whole group (about 82%) a further adjustment has been made based on recommendations in the OECD (2012) review[7] using the following formula:

$$VSL_{Slovakia} = \left(\frac{GDPPC_{Slovakia}}{GDPPC_{EU28}}\right)^{0.8} VSL_{EU28}$$

The formula is based on the reasoning that the VSL increases with per capita GDP, reflecting a higher willingness to pay (WTP) to reduce the risk of death in richer countries. The percent increase in WTP per one percent increase in per capita income is estimated in the literature as not being unity but slightly below that – a value of 0.8 is the best estimate according to the OECD. Applying the above formula provides VSL values for Slovakia of €3,138,572 (mean), €1,569,287 (low) and €4,707,859 (high).

The VLYL estimates in the literature are €52,000 (median) and €120,000 (mean) for the EU28[8]. Adjusting these values, which are in 2000 prices, for inflation gives €71,425 (median) and €164,827 (mean). Adjusting further for the fact that GDP per capita in Slovakia is 82% of the EU28 average gives VLYL values of €61,101 (median) and €141,002 (mean). An alternative way to estimate VLYL is the figure used for policy purposes in the country. A value for a life year is set in the Slovak legislation to determine how much a new medicine can cost per added life year. This benchmark is set at max. 41-times the monthly average wage in Slovakia. As the average monthly wage in 2018 was €1,013, the valuation of an additional year according to legislation is €41,533, somewhat lower than the numbers obtained from the literature.

In order to apply the VLYL to the premature death estimates the number of life years associated with a premature death are required and depend on whether the health impact is acute or chronic. Acute impacts have fewer years of life lost than chronic ones. The EEA (2019) uses an estimate of 10.2 years for $PM_{2.5}$ all-cause deaths. The same figure has been used here.

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[3] Note: Directive 2008/50/EC doesn't set a daily limit for PM2,5, WHO guideline is used instead, yearly value for exposure concentration obligation is used.

[4] https://strata.org/pdf/2017/vsl-full-report.pdf

[5] http://old.heatwalkingcycling.org/index.php?pg=requirements&act=vsl&b=1.

[6] A further adjustment could be made to account for growth in per capita GDP between 2011 and 2019 in the EU28. This is something that can be considered in the revisions to the estimates.

[7] OECD (2012), Mortality Risk Valuation in Environment, Health and Transport Policies. OECD: Paris.

[8] http://en.opasnet.org/w/Value_of_a_life_year_(VOLY)#cite_note-2

In the case of morbidity, a range of valuations are needed, one for each endpoint. The ones that matter most for Slovakia are: RADs, cases of chronic bronchitis and workdays lost. For RADs and cases of chronic bronchitis the EU CAFÉ study[9] is used. The values for morbidity endpoints in that study have been used extensively in EU National Air Pollution Control Programme documents and the study and figures have not been significantly updated in methodological terms. The estimate for a RAD was €130, and for a case of chronic bronchitis €190,000 (with a range of €120,000 to €250,000). Figures are per day for the EU and in 2000 prices.

Adjusting these figures for inflation and the difference in GDP per capita between the EU28 and Slovakia gives the following estimates: RAD: €172.75; case of chronic bronchitis: €223,255 (lower bound: €141,003, upper bound: €293,756). For workdays lost the average wage in Slovakia has been used giving a cost of €28.36/day[10]

All of these calculations are made on the Mean Reductions sheet of the toolbox for the mean reductions in physical impacts.

Cost-benefit estimations (fiscal and economic costs)

Estimates of value of health impact reductions are then compared to costs of proposed intervention. We make one comparison based on the fiscal costs and another based on the economic costs. The benefits are taken as the same in both cases; they consist of the health gains from the reduced concentrations of air pollutants measured in monetary terms. They only represent financial flows in the case of reduced morbidity expenditures, but the mortality benefits are not measured on a financial basis. Hence to that extent, while the analysis based on economic costs is a full economic cost benefit analysis, the one based on fiscal costs is a hybrid, with the costs being net outlays by the public sector and the benefits being full economic benefits.

In undertaking the present value calculations, it is necessary to discount future costs and benefits at an agreed rate. For this purpose, we have used the EC guidance values for financial and economic cost benefit analysis in cohesion countries, which include Slovakia (see footnote 20 in the report). They recommend a discount rate of 4% for financial cost benefit analysis and one of 5% for economic cost benefit analysis. Changes to these rates can be made but there it requires a change in the formula in column B of the worksheets, replacing the current value with the desired alternative value.

The toolbox then includes 3 benefit-to-cost analysis for each fiscal and economic costs:

- BCA1 assumes that all the calculated reductions between 2020 and 2030 would be caused by the NAPCP. That would mean that without implementation of the Programme no improvement in air quality would happen, which is not true. This is therefore calculated as the maximal possible value but not used any further (can be found in sheets E_BCA1 for economic costs and F_BCA1 for fiscal costs).

- BCA2 attributes 46 % of the reductions to the NAPCP. This is an attribution that was made by the previous joint project between the World Bank and the Ministry of Environment of Slovakia (can be found in sheets E_BCA2 for economic costs and F_BCA2 for fiscal costs).

- BCA3 extends the horizon up to the year 2040, which would further improve the results, but is only speculative (can be found in sheets E_BCA3 for economic costs and F_BCA3 for fiscal costs).

[9] AEA (2005) Service Contract for carrying out cost-benefit analysis of air quality related issues, in particular in the clean air for Europe (CAFE) programme. Methodology for the Cost-Benefit analysis for CAFE: Volume 2: Health Impact Assessment

[10] https://countryeconomy.com/national-minimum-wage/slovakia The data gives a minimum annual wage of €6,240. It is assumed that 220 days are worked per year.