Further explanation of methods used for monetizing impacts from air pollution

CE Delft

Committed to the Environment

Further explanation of methods used for monetizing impacts from air pollution

Delft, CE Delft, July 2020

Publication code: 20.180005.092

Air polution / Damage / Monetizing / Prices / Methodology

This paper is prepared by: Sander de Bruyn

1 Introduction

This short note[1] tries to explain what approach has been chosen in the quantification of the unit damage costs for air pollution in the Environmental Prices Handbook 2018 (EU28 version) and the DG Move Handbook on External Costs of Transport. It should be regarded as an explanatory note to Annex C.3 in the Handbook of External Costs of Transport which is largely the same as Annex B.3 in the Handbook of Environmental Prices. Both handbooks have been frequently used in policy evaluations, but some questions have been raised to what extent they are consistent with the HRAPIE framework from the WHO (2013) on the recommended values to be taken into account in cost benefit analysis. A recent analysis suggested that, while the main categories of CRFs from the Handbook of DG Move seem to be in line with the HRAPIE framework, some questions can be asked especially with respect to the mortality impacts from O_3 and NO_2.

This short note explains in more detail how the HRAPIE recommendations have been implemented in both handbooks for the mortality impacts from O_3 and NO_2. This note shows that for NO_2, the mortality impact is in line with both the HRAPIE recommendations (WHO, 2013) and the more recent COMEAP study (COMEAP, 2018). For O_3 our approach is not in line with the recommended value from the HRAPIE study but this is done to maintain consistency with the environmental modelling used in both handbooks. We show that the combination of the chosen environmental modelling and our adjusted O_3 mortality rates result in similar estimates for mortality from O_3 that strictly follow the WHO Guidelines. Therefore, this deviation has a negligible impact on the total valuation of impacts from pollutants that cause O_3.

To sum up: we acknowledge that there have been small deviations from the HRAPIE recommendations but that these have been motivated to cope with other uncertainties or approaches taken in the whole impact-pathway approach. As we will show this has a negligible impact on the total unit damage costs. Therefore we regard the approach taken in both handbooks still consistent with HRAPIE recommendation in the context of estimating unit damage costs.

Box 1: Handbooks from CE Delft estimating external costs

Within the Handbook of External Costs (CE Delft; INFRAS; TRT, 2019) and the Handbook of Environmental Prices (CE Delft, 2018) unit damage costs of emissions have been calculated and expressed in €/kg emission so that an emission can be valued for its external costs. Human health impacts constitute a large part of these damage costs. Human health impacts have been estimated using an impact-pathway approach that describes the chain from an emission towards a change in concentration towards a change in an impact on human health that can be valued. The impact pathway approach uses thus three different methodological tools: (i) atmospheric modelling that describes the relationship between emissions and concentrations; (ii) concentration response functions that describe the relationship between concentration and human health, and (iii) valuation that values the impacts on human health. Within both handbooks fifteen different concentration response functions have been used to estimate the impact of the concentration of air pollutants (PM_2,5, PM_{10}, O_3, NO_2) on human health. These CRFs have been combined with information on characterisation factors (Goedkoop, et al., 2013) from the lifecycle analysis, atmospheric modelling (NEEDS, 2008) and a valuation framework based on a literature review, to come up with an estimation of the so-called unit damage cost of pollution. This framework has been developed and approved in close cooperation with scientific expert meeting groups and steering committees.

[1] The author expresses his thanks to Rob Maas of the National Institute of Public Health and the Environment (RIVM) for comments on an earlier draft of this. The usual disclaimer applies.

2 Consistency with the HRAPIE framework

2.1 General outline and methodology

Both handbooks take the NEEDS project (NEEDS, 2008) and the EcoSense modelling results as starting point of the analysis and subsequent modifications on these modelling results have been applied on: (i) atmospheric modelling; (ii) population density and age structure of population; (iii) valuation; (iv) concentration response functions. In both handbooks the concentration response functions from the NEEDS project were checked against the (WHO, 2013) HRAPIE framework. If we found substantial differences in the approach, we decided to update the NEEDS CRFs with the more recent information from the WHO HRAPIE framework.

Box 2: The WHO HRAPIE framework applied in the handbooks

The WHO (2013) developed the HRAPIE framework to standardize the use of concentration response functions used in cost-benefit analysis to estimate the health impacts from air pollution. The WHO (2013) classifies impacts as Group A or Group B:

- Group A: pollutant-outcome pairs for which enough data are available to enable reliable quantification of effects (also called the limited impacts).
- Group B: pollutant-outcome pairs for which there is more uncertainty about the precision of the data used for quantification of effects (also called the extended impacts).

In our check against the WHO HRAPIE framework we checked against both Group A and Group B. So in theory, our impacts should include both Group A and Group B.

HRAPIE recommends in CBA to use four scenarios:

1. A limited scenario with only Group A impacts.
2. Range analysis with the uncertainty ranges of the limited impacts included.
3. An extended scenario with Group A + Group B impacts.
4. Range analysis with the uncertainty ranges of the extended impacts included.

It should thus be emphasized that the valuation framework in the DG Move handbook is in essence related to the third scenario. Such values can be used in cost-benefit analysis but one should notice that in order to be consistent with the WHO (2013) framework researchers may have to present the other scenarios as well.

The third scenario has been chosen by us because the HRAPIE framework is more than five years old and over the years more and more evidence on detrimental health impacts from air pollution comes available.
We noticed that important impacts, such as diabetes (Bowe, et al., 2018)had not yet been incorporated in the HRAPIE framework. In addition, including group A and B seemed to be more in line with what has been done in earlier work, such as NEEDS (2008) or Ricardo –AEA, et al., (2014)

A recent note has suggested that the handbooks are not entirely consistent with the HRAPIE framework, in particular with mortality impacts of O_3 and NO_2. These will be elaborated in more detail hereafter.

2.2 Mortality impacts O_3

It is noticed that the Handbook of External Costs does include chronic mortality impacts whereas HRAPIE does not recommend this for all-cause mortality but only for respiratory mortality as an alternative for all-cause mortality. In a strict sense, this is true, but the discussion with respect to mortality aspects has to be investigated in the broader impact-

pathway approach that was selected to investigate the O_3 impacts from NMVOC (the main precursor of ozone in the northern part of Europe).
Within the handbook of Environmental Prices (the predecessor of the handbook of External Costs for DG Move) a discussion was being held among experts with respect to three aspects:

1. Whether NMVOC would also cause secondary aerosols which would cause mortality as well.
2. Whether acute mortality impacts would be extended to chronic mortality.
3. Whether acute mortality and chronic mortality would be valued differently, as has been done in NEEDS (2008)

These three choices would have important impact for the valuation of NMVOC in the Handbook for DG Move. If we would make the choice (i) not to attribute secondary aerosols to NMVOC; (ii) would only stick to acute impacts and (iii) value these with the same YOLL as for chronic impacts, the total damage costs for NMVOC would accrue to € 0.5/kg as an average for the EU28, while if we would include secondary aerosol formation, chronic mortality CRFs and a higher valuation of acute mortality, the NMVOC valuation would accrue to € 3.5/kg.

Within the Handbook of Environmental Prices (CE Delft, 2018) we have adopted the ReCiPe framework for lifecycle analysis. Within this framework, no impact of NMVOCs on secondary organic aerosol formation have been identified as these impacts differ greatly between the various types of NMVOCs (so that a simple factor would not represent the scientific uncertainty on this) and there is not enough evidence that the impacts from secondary organic aerosols (SOA) should be valued similar to human health as secondary inorganic aerosols (SIA). However, we noticed that within the CAFÉ-CBA framework (see e.g. (EEA, 2014; Holland, 2014) secondary organic aerosols have been included with a characterisation factor of 0.09 to PM_{10} (and probably valued similar to SIA).

So in the end it was decided that the Handbook of Environmental Prices would follow characterisation through LCA models, like ReCiPe, and not to include SOA impacts from NMVOC. To counterbalance this, it was included to include chronic impacts to bring in a balanced estimate. In a sensitivity analysis (not reported in the DG Move Handbook, but reported in the Dutch Handbook of Environmental Prices, Annex C.5) we investigated the impact of this assumption. It was concluded that assigning a SOA impact on NMVOC (and not including a chronic impact from O_3 would have resulted in a slightly higher valuation for NMVOC but that this would fall within confidence intervals.

Therefore, our valuation framework is still relatively similar to that of others (e.g. (EEA, 2014)) that have included chronic impacts through SOA even though in a strict sense one could claim that we do not follow the WHO HRAPIE recommendations. But the total valuation stemming from the total assumptions of SOA, valuation and CRFs show that our results are conservative towards the damage from NMVOC emissions.

2.3 Mortality impacts NO_2

Chronic (long term) mortality NO_2 impacts are given in HRAPIE as a group B as it is noticed that some of the long-term NO_2 effects may overlap with effects from long term $PM_{2.5}$ (up to 33%). WHO warns against double counting with $PM_{2.5}$ all-cause mortality for measures that reduce both NO_x and $PM_{2.5}$.

Within the steering group of the Dutch Handbook of Environmental Prices (CE Delft, 2017) it was emphasized to include this because of the following reasons:
- The main reason why WHO (2013) considers it as category B is related to the issue of double counting. We were encouraged to come up with ways to solve this issue.
- Experts expecting that new evidence (through the COMEAP study) would enforce the chronic impacts of NO_2 on mortality.

There was discussion within the expert group as to what extent we should use a threshold value, as in WHO (2013) for impacts above the 20 ug/m^3 as the COMEAP study (which was not published at that time) would find evidence for not using a threshold. The same applies to the age group fraction, as the WHO (2013) reports only impacts for adults aged 30+.

In the end we decided to include chronic mortality of NO_2 on the basis of category B using the threshold in annual mean exposure and the age group fraction. The double counting impact was addressed through characterisation factors from ReCiPe (Goedkoop, et al., 2013) implying that on average 33% of NO_x would eventually be transformed into SIA (secondary inorganic aerosols).[2] Using the RR from $PM_{2.5}$ mortality we deduced this amount from the NO_2 mortalityrate.

We fully agree here that this has been a very rough approach, which:
- does not take into account specific local circumstances in the SIA formation from NO_2 (see also footnote 1 for justification);
- does not properly take into account the statistical interference in the original studies estimating the impacts from chronic NO_2.[3]

In the end of the text in the Annex C in the External Cost Handbook a slightly confusing statement is made where we say that: “This implies that the chronic health damage attributable to NO_2 should be a factor 3 higher than assumed in NEEDS, based on its contribution to PM formation.”

To clarify: we did not simply use here a factor 3: this statement compared the impact from NO_2 pollution for someone living in an area of pollution over 20 ug/m^3 of 30+ years old which would have, on average, impacts a factor 3 higher than if only SIA impacts from NO_2 were considered. Under the NEEDS project NO_x was only causing all-cause mortality through the formation of secondary aerosols and the amount of SIA formation differs per grid cell. We meant to say here that, on average, the total impact of NO_2 would be a factor 3 higher when calculated with the characterisation factors from ReCiPe. Therefore the correct statement of this sentence should be: ‘This implies that the chronic health damage attributable to NO_2 should be a factor 3 higher than assumed in *ReCiPe*, based on its contribution to PM formation.’

[2] We want to emphasize here that SIA-formation was determined for each country separately through the EcoSense-modelling results. The factor 3 was only used by us as an approximation of the ‘double counting issue’. Such generalized approach can be defended by the fact that the concentration response functions from WHO (2013) also give a ‘generalized’ impact of NO_2 on public health. In areas where NO_x causes much more SIA, the mortality rates may be higher than in areas where NO_x causes relatively little SIA.

[3] COMEAP (2018) says about this: “If the concentrations of a group of pollutants are correlated with each other, and if each pollutant has an effect on mortality, then the statistical associations of each individual pollutant with mortality will, to some extent, also reflect the effects of other pollutants in the group.”

In more recent work we also investigated the COMEAP project (COMEAP, 2018) in this respect as this study very explicitly elaborates the issue of statistical interference. Basically this study does exactly what the steering committee of the Dutch handbook asked us to do. The authors of the COMEAP study states:

“We explored several approaches to account for possible confounding of the NO_2 mortality associations by associations of mortality with $PM_{2.5}$. However, we concluded that none of these potential approaches was appropriate and we have decided against formally deriving an NO_2 coefficient adjusted for effects associated with $PM_{2.5}$. Instead we have applied our judgement, informed by the available evidence, to propose a reduced coefficient which may be used to quantify the mortality benefits of reductions in concentrations of NO_2 alone, where this is necessary.”

It is at least clear that COMEAP did not come to agreement with respect to the question if this single impact could be isolated. Nevertheless, the study states that “The majority of the Committee supported reducing the unadjusted coefficient by around 20% to allow for the effects more closely associated with $PM_{2.5}$ concentrations. The figure of 20% was arrived at by detailed but informal assessment of the multi-pollutant results from four cohorts considered less subject to bias, e.g. without strong correlation between NO_2 and PM.”

On quantification, this study suggest, very carefully, that one may consider using an all-cause RR of 1.006 to 1.013 per 10 $\mu g/m^3$ of NO_2 for estimating the effects attributable to NO_2 alone without thresholds or age groups. If we would not have used thresholds or age groups, the CRF that we used would be equivalent to 1.0076 per 10 ug/m^3, so in line with COMEAP (2018), rather on the lower-end of the range. That again gives us some confidence that the approach chosen is in line with the scientific evidence although it is indeed good to emphasize the scientific uncertainty related to the NO_x estimate.

To sum up, WHO (2013) recommends including all-cause mortality for NO_2 but warns against double counting with measures that also reduce $PM_{2.5}$. Within the handbooks we have attempted to correct for this double counting. The outcome seems to be in line with the range recommended by the COMEAP study, on the lower edge of this range, even though the quantification was only approved by the majority (thus not unanimously) of the COMEAP team.

2.4 Other impacts

Morbidity impacts in general are less important in the total unit damage costs than mortality impacts. Most of the morbidity impacts are in line with the WHO (2013) with a few exceptions. The exceptions are listed as follows.

PM_{10} prevalence of bronchitis in children aged six to twelve years

This impact was not included in the NEEDS framework but is included in the WHO HRAPIE framework. The reason not to include this in the Handbook of External Costs was that it was not used in the NEEDS framework plus the fact that it was considered as a category B impact only. Inclusion of this impact would have required additional calculations and we perceived the information from the WHO (2013) that the impact on the value would be very low: as the RR is relatively low (about 75% of adult COPD) and the valuation of the prevalence of bronchitis in children is presumably quite low (the incidence rate is about 18%), it would barely influence the results. A very preliminary calculation learned us that the impacts most likely would be less than 0.3% of the total $PM_{2.5}$ costs and almost entirely dependent on the valuation for which we did not have good literature at hand.

Therefore we excluded this category.

PM_{10} differentiation between are of exhaust

PM_{10} emissions from brakes and tires have been differentiated according to the country of exhaust but not the location of exhaust (e.g. cities, rural). The reason is primarily that the handbook wants that valuation of emissions occurs through $PM_{2.5}$ as these estimates are more accurate. The share of emissions from brakes and tires are relatively small and it was decided that it would not be required the effort to differentiate these to location.

3 Conclusions

It has been argued that the estimates in the Handbook on External Costs of Transport (CE Delft; INFRAS; TRT, 2019) and Handbook of Environmental Prices (CE Delft, 2018) are not entirely in line with the WHO HRAPIE recommended concentration response functions, especially in the area of mortality of NO_2 and O_3. This short notice has explained in more detail certain choices made in these handbooks where they seem to diverge from the WHO HRAPIE framework and compares the results of these choices on the final valuation of emissions.

The WHO recommended concentration response functions are one of the three methodological steps in the impact-pathway approach. The handbooks, and the scientific steering committees that were guiding these handbooks, recommended us to investigate all three aspects simultaneously. This has resulted in the following adaptations from the WHO HRAPIE framework:
- For NMVOC impacts (O_3) chronic mortality was included in the CRF and not as a result of secondary organic particulate matter formation as has been done in other research (e.g. Holland, 2014; (EEA, 2014)). This was done to remain consistency with the environmental modelling of impacts through ReCiPe lifecycle analysis. It was argued that excluding both secondary organic aerosols and chronic impacts would have resulted in a too low valuation of the impacts of NMVOC (as has been done in the German Handbook Methodenkonvention (UBA, 2019) When we compare our values against the work at IIASA and EEA, we see that our estimates are in line with such works but on the conservative side.
- HRAPIE recommends including all-cause mortality from NO_2 in cost-benefit analysis but warns against double counting with all-cause mortality from $PM_{2.5}$. In our approach we have attempted to correct for this double counting. We evaluated in the present paper our results against new insights from the COMEAP study (that was not available at the moment of writing) and we see that our approach is similar to the lower part of the range that the majority of COMEAP members recommends.
- For prevalence of bronchitis in children aged six to twelve, we observed that this was not part of the original NEEDS estimations. We concluded that the valuation of this effect is uncertain with wide different ranges in the literature. The impact on total $PM_{2.5}$ costs would be minimal, that is why it was excluded from the analysis.

These decisions have been carefully considered and taken in consultation with an academic steering committee. We feel that they do lay within the usual uncertainty bounds that should be considered when applying such figures. A simple ‘yes’ or ‘no’ verdict as to the extent to which our approach complies to WHO HRAPIE recommended CRFs does to our opinion only limited justice to the complexity and uncertainty of the underlying models.

4 Literature

Bowe, B. et al., 2018. The 2016 global and national burden of diabetes mellitus attributable to PM2·5 air pollution. *Lancet Planet Health,* 2(July), pp. 301-312.
CE Delft, 2017. *Handboek Milieuprijzen 2017 ; Methodische onderbouwing van kengetallen gebruikt voor waardering van emissies en milieu-impacts,* Delft: CE Delft.
CE Delft, 2018. *Environmental Prices Handbook EU28 version : Methods and numbers for valuation of environmental impacts,* Delft: CE Delft.
CE Delft; INFRAS; TRT, 2019. *Handbook on the external costs of transport - version 2018,* Delft: CE Delft.
COMEAP, 2018. *COMEAP, 2018. Associations of long-term average concentrations of nitrogen oxide with mortality,* Chilton: Committee on the Medical Effects of Air Pollutants (COMEAP).
Dutch Health Council, 2018. *Gezondheidswinst door schonere lucht,* Den Haag : Gezondheidsraad (Dutch Health Council)..
EEA, 2014. *Costs of air pollution from European industrial facilities 2008–2012,* Copenhagen: European Environment Agency (EEA).
Goedkoop, M. et al., 2013. *ReCiPe 2008, A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level; First edition Report I: Characterisation. Update may 2013,* Bilthoven: RIVM.
Holland, M., 2014. *Cost-benefit Analysis of Final Policy Scenarios for the EU Clean Air Package Version 2 Corresponding to IIASA TSAP Report 11, Version 1,* s.l.: EMRC.
Holland, M., 2014. *Cost-benefit Analysis of Final Policy Scenarios for the EU Clean Air Package : Version 2 Corresponding to IIASA TSAP Report #11, Version 2a.* [Online] Available at: https://ec.europa.eu/environment/air/pdf/TSAP%20CBA.pdf [Accessed 2020].
NEEDS, 2008. *NEEDS deliverable No 1.1.-RS 3a Report on the procedure and data to generate averaged/aggregated data. Priority 6.1 (...) Sub-priority 6.1.3.2.5: Socio-economic tools and cencepts for energy strategy,* Brussels: European Commission..
Ricardo-AEA; TRT; DIW-Econ; CAU , 2014. *Update of the Handbook on External Costs of Transport – Final Report, London.,* London: Ricardo-AEA.
UBA, 2019. *Methodenkonvention 3.0 zur Ermittlung von Umweltkosten - Kostensätze Stand 02/2019,* Dessau Roßlau: Umweltbundesamt (UBA).
WHO, 2013. *Health risks of air pollution in Europe – HRAPIE project. Recommendations for concentration–response functions for cost–benefit analysis of particulate matter, ozone and nitrogen dioxide,* Geneva: World Health Organization (WHO).
WHO, 2014. *WHO Expert Meeting: Methods and tools for assessing the health risks of air pollution at local, national and international level, meeting report 12-13 May ,* Bonn: WHO.