20th International Conference on
Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes
14-18 June 2020, Tartu, Estonia

OPERATIONAL HEALTH DAMAGE COST MODEL FOR MUNICIPALITY POLICY ASSESSMENTS

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Abstract: Health externalities should be taken into account more widely in European policy making at different levels. We have developed an easy-to-use tool ihQ for city and municipality level experts to assess health damage costs caused by local air pollution emission sources. Here we present the main features of ihQ and demonstrate the use with examples.

Key words: *fine particles, emissions, human health, costs*

INTRODUCTION

External costs caused by air pollution are often neglected in the policy-making because of lack of tools to quantify the externalities. Health damage due to fine particulate matter ($PM_{2.5}$) concentrations in ambient air has been shown to be a major source of external costs in Europe (EEA, 2014).

According to WHO, Finns breath the cleanest air in the world. However, ambient air pollution of fine particles ($PM_{2.5}$), respirable particles (PM_{10}), ozone (O_3) and nitrogen dioxide (NO_2) has been estimated to cause a disease burden equivalent to 34 800 DALYs or 2000 premature deaths in 2015, of which $PM_{2.5}$ was responsible for 74% (Lehtomäki et al., 2018). Major fraction of $PM_{2.5}$ concentrations in Finland are caused by long-range transported air pollution. However, there is also a significant component caused by local emission sources, especially in cities and urban areas where population exposure to $PM_{2.5}$ is relatively high. The impact of local sources on the concentrations and population exposure is highly dependent on the location of emission sources in relation to population densities in the vicinity of the sources (Korhonen et al., 2019), i.e. the size and characteristics of the cities.

To support the assessment of the health externalities of air pollution caused by different local emission sources, we have developed an easy-to-use tool ihQ. The tool is targeted for city and municipality level experts and policy-makers to assess external health damage costs caused by local emission sources, or, rather, monetary value of health benefits attained by local emission reductions.

Earlier we developed an air pollution damage cost model IHKU targeted primarily for national level policy-makers (Kukkonen et al., 2020). In IHKU model training sessions, soon after launching the model, it became apparent that there is a need for spatially more explicit tool for municipality level policy-making. Therefore we developed a version of the IHKU model, that allows users to perform calculations separately for 11 emission source sectors in any of the 310 municipalities in Finland.

The modelling set-up and sector specific results for the modelling chain from emissions to health impacts and costs are reported in detail in Kukkonen et al. (2020), therefore these are touched only briefly here. The purpose of this abstract is rather to present features of ihQ from the user perspective and demonstrate the use with real-life examples.

METHODOLOGY

The ihQ tool can be used to estimate the effect of changes in air pollution emissions from different emission source sectors on $PM_{2.5}$ concentration induced human health impacts. The modelling covers both primary $PM_{2.5}$ and secondary formation from main inorganic PM precursor gases. The health impacts are expressed as monetary values, i.e. health damage costs. IhQ output is based on the same modelling set-up as in the country level air pollution damage cost model IHKU. The main difference is that in ihQ the user can study emission changes of an emission source sector for a selected municipality, while in IHKU the studied sources were defined as averages of urban or non-urban areas calculated over the whole of Finland. The modelling set-up of the country-level IHKU is reported in detail in Kukkonen et al. (2020), therefore only a brief summary is presented in the following.

Emissions

The ihQ tool includes the most important local sources of air pollutants emissions that contribute to $PM_{2.5}$ outdoor concentrations. The idea is that the user enters the amount of emission change (decrease or increase from baseline state) in the city or municipality in question. The emission sources and pollutants that the user can enter are presented in Table 1. To feed into atmospheric models, the emissions from low height sources are spatially resolved to 250 x 250 m horizontal grid resolution for each sector in the Finnish Regional Emission Scenario (FRES) model of the Finnish Environment Institute (Karvosenoja, 2008; Karvosenoja et al., 2020). Power plants and industry sources are represented as point sources with actual stack height and location information.

Table 1. Emission sources and pollutants that can be entered into the ihQ tool.

Low emission height sources	**High emission height sources**
Road transport, non-exhaust, $PM_{2.5}$	Power plants and industry, $PM_{2.5}$
Road transport, exhaust, $PM_{2.5}$	Power plants and industry, SO_2
Machinery and off-road, $PM_{2.5}$	Power plants and industry, NO_X
Residential houses wood combustion stoves, $PM_{2.5}$	
Recreational houses wood combustion stoves, $PM_{2.5}$	
Residential houses wood combustion boilers, $PM_{2.5}$	
Road and off-road transport and machinery, NO_X	
Agriculture, NH_3	

Modelling of primary $PM_{2.5}$

For the dispersion of primary $PM_{2.5}$ from low emission height sources, ihQ uses source-receptor matrices based on a Gaussian multiple source Urban Dispersion Modelling system by the Finnish Meteorological Institute UDM–FMI (Karppinen et al., 2000) applied in the FRES model.

Modelling of secondary $PM_{2.5}$

For high emission height sources and formation and dispersion of secondary particles, the System for Integrated modeLling of Atmospheric coMposition (SILAM) chemical transport model was used (Sofiev et al., 2015).

Population exposure

To calculate the change in population exposure to $PM_{2.5}$ caused by emission change in each sector, the modelled concentrations were combined with population data. To define emission – population exposure ratios, i.e. population weighted concentrations (PWC), for each emission source sector and municipality, we used a different approach for primary and secondary $PM_{2.5}$.

Primary $PM_{2.5}$ emissions from low emission height sources cause concentration gradients at local level near the sources, and the characteristics of cities in terms of population densities, location of emissions sources etc. have considerable impact on average polation exposures. Therefore, for these, PWCs for each emission source sector were calculated separately for each city bigger than 50 000 inhabitants (21 cities). For smaller cities and municipalities, average PWCs for each emission source sector were calculated for two classes: 10 000 – 50 000 and below 10 000 inhabitants.

For high emission height sources, i.e. power and industrial plant point sources, the PWCs caused by primary $PM_{2.5}$ emissions were calculated separately for three areas with different degrees of urbanization: i) Helsinki area, ii) other municipalities with more than 50 000 inhabitants and iii) smaller municipalities. For precursors of secondary $PM_{2.5}$ (SO_2, NO_x and NH_3), one PWC value was used for the whole country for each sector (point sources, transport and agriculture). For more details, see Kukkonen et al. (2020).

Health impacts

Linear response functions were used for the changes in $PM_{2.5}$ concentrations (WHO, 2013). The following health endpoints were considered, as in the HRAPIE project of the WHO: Mortality, chronic bronchitis, cardiovascular and respiratory hospital admissions, incidence of asthma, work days lost and restricted activity days. Background risks were obtained from Statistics Finland and Eurostat.

Economic impacts

For the costs for the health endpoints in ihQ, we used a recent population weighted Value of Statistical Life (VSL) for Nordic countries 3.5 M€ to represent the Finnish case. The Nordic VSL estimate is still unpublished, based on benefit transfer from the global meta analysis of VSL estimates from Stated Preference surveys (Lindhjem et al., 2011). In the national level IHKU tool (Kukkonen et al. 2020) we used a lower VSL 2.65 M€ taken from literature, according mainly to the previous EU-wide impact assessments by Hurley et al (2005) and Holland (2014). We choose to use the Nordic VSL 3.5 M€ because recent studies show mainly higher VSL values than what was used in previous EU-wide assessments.

USER INTERFACE AND EXAMPLES

The user of ihQ first selects the municipality in question from the list of 310 municipalities, and feeds in the amounts of annual emission reductions (or increases) in the selected sources (Figure 1). For each of the sector, total annual emission amount of the municipality is displayed in parenthesis to assist the user in estimating the range of possible emission reductions. On the right-hand side, the resulted damage costs for each sector are given as a bar figure.

The following presents hypothetical examples of ihQ model application using real-life emission reduction estimates.

Example 1: The city of Helsinki has prepared The Carbon-Neutral Helsinki 2035 Action Plan with 147 measures to mitigate its greenhouse gas emissions (City of Helsinki, 2018). Several of these measures, especially the ones concerning road transport, potentially have impact also on human health. One of such measures is inner city resident parking fee increase, which would decrease traffic intensities within Helsinki. Based on the assessment carried out in Vienna (Hössinger and Uhlmann, 2012), doubling the resident parking fees would lead to an 8.8% decrease in traffic amounts for those who live within the resident parking fee area (12.6% of car owners in Helsinki). This would mean 1.1% decrease in total traffic amounts in Helsinki, i.e. 0.19, 0.40 and 16 tons/year decrease in non-exhaust $PM_{2.5}$, exhaust $PM_{2.5}$ and NO_x emission, respectively.

Example 2: Savolahti et al. (2016) has estimated that information campaigns for citizens about proper wood stove use could decrease high-emission combustion practices by 5-50%. This would imply approx. 1-10% decrease in residential wood stove $PM_{2.5}$ emissions. Estimating here a 5% emission decrease for Helsinki, it gives 1.7 tons/year reduction for information campaigns.

Example 3: Helsinki energy company Helen, as a part its goal to reach carbon neutrality by 2035, is planning to replace its coal-based district heating with renewable and non-combustion heat sources. It has been estimated that roughly 25% of the production in Hanasaari B power plant could be replaced using heat recovery and heat pumps to feed into the district heating network (www.hel.fi/static/kanslia/energy-challenge/key-facts-and-figures-district-heating-system-in-helsinki.pdf). That would mean approx. 1.9, 290 and 470 tons/year decrease in $PM_{2.5}$, SO_2 and NO_x emissions, respectively.

Figure 1 shows the ihQ user interface with the above examples of emission reductions entered into the tool on the left-hand side. The figure on the right gives the resulting health benefits due to decreased $PM_{2.5}$ concentrations and population exposure expressed as monetary values. The highest health benefits of the examples are attained in the emission reductions in Hanasaari B power plant, which are presented as the top section in the figure. Total benefit of the three examples equals to approx. 6.5 Million €/year.

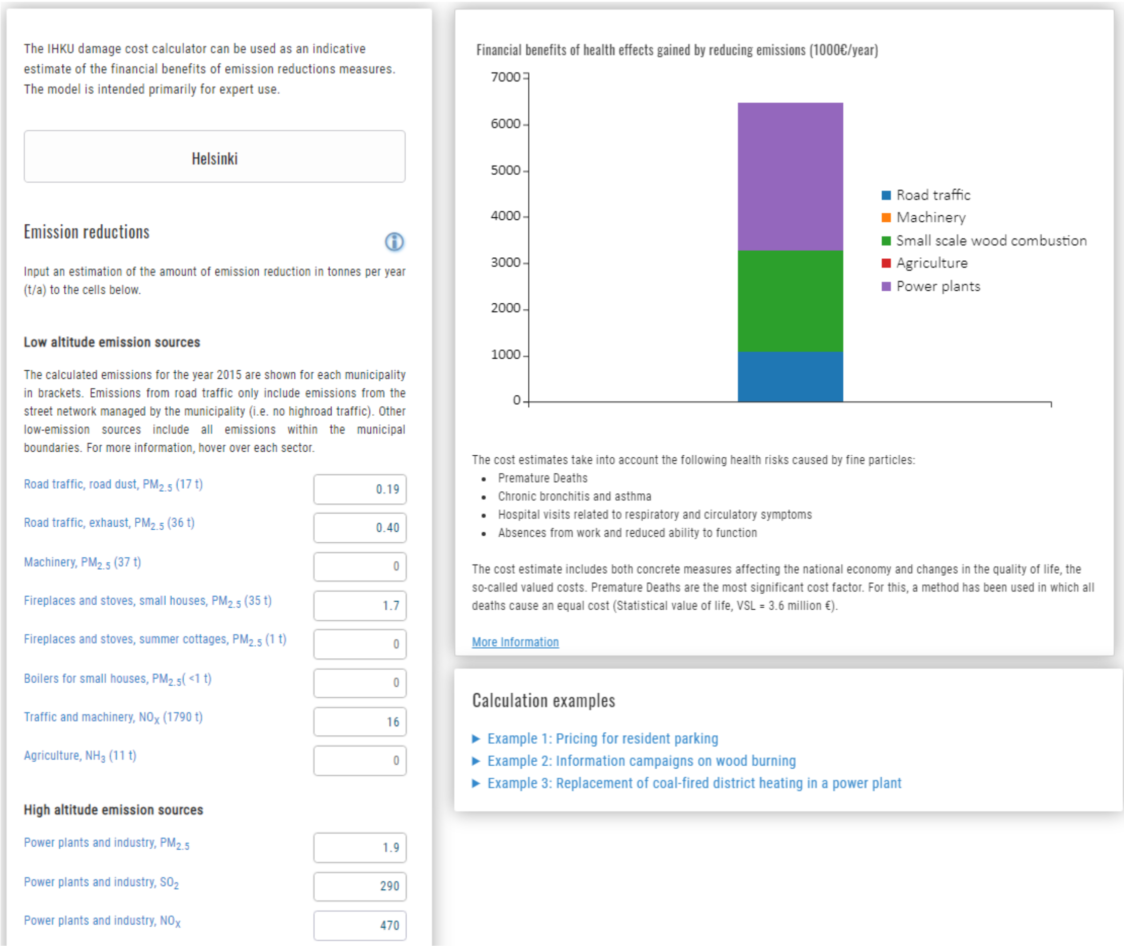

Figure 1. User interface of ihQ with calculation examples.

CONCLUSIONS

We have presented an easy-to-use tabulated method for evaluating the public health costs of air pollution for municipality level experts and policy-makers and programmed an internet-based computation tool, which is publicly available. There are several European and national level health damage cost studies and models existing. Many of the existing national level health damage cost studies provide different estimates for different types of areas (urban, rural etc.) and/or at county level. They also emphasize the importance of characteristics of the areas with emissions, especially population densities. IhQ will add new results, and especially bring new information about health damage costs for cities of different sizes and sparsely populated areas. Health costs per unit emissions vary vastly in different parts of Finland, from relatively densely populated Helsinki (e.g. for residential wood stoves 800 € $kg(PM_{2.5})^{-1}$) to more sparsely populated smaller municipalities (55 € $kg(PM_{2.5})^{-1}$, respectively).

The implementation of air pollution health damage cost models is recommended by the Finnish National Air Pollution Protection Program 2030; therefore it is considered a high national priority. User training sessions of ihQ have been implemented for municipality experts in late 2020 and early 2021 and the model will be developed further based on the feedback.

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