The anonymous referee's comment on 12.11.2019 is on black font below, and the authors' response in on blue.

Referee's comment

The paper aims at estimating monetized health impacts caused by emissions of 1 t of PM2.5 or 1 t of PM2.5 precursors. The monetized health impacts are given distinguishing between emissions of main source categories and emissions in urban vs. non-urban areas. The calculation is made according to the state of science; the science used is sound, the methodology is well described, calculations have been thoroughly made.

Authors' response

Thank you for these positive comments.

Referee's comment

However, progress beyond the current state is not made, new developments are not addressed.

Authors' response

The manuscript includes in our view also progress beyond the current state-of-the-art.

First, the modelling has been performed using a very fine spatial resolution, up to 250 x 250 m^2; these have not previously been used for such a geographically extensive area. In comparison, e.g., Heo et al. (2016) used as the basic material the predicted concentrations on a spatial resolution of 36 x 36 km^2, i.e., two orders of magnitude coarser than in the present study. This resolution scale is characteristic of all the previous studies on public health costs.

We have previously shown (Karvosenoja et al., 2010, Korhonen et al., 2019) that the exposure values evaluated using integrated assessment models can be very sensitive to the methodology. In particular, exposure values can substantially increase with an increasing spatial resolution. Karvosenoja et (2010) showed that using a finer spatial resolution, from 10 km to 1 km, resulted in an increase of the population weighed concentration caused by traffic emissions by an order of magnitude. It is therefore essential to use a sufficiently fine model resolution in view of the health impacts. This is especially important for primary particles from emission sources at fairly low emission heights.

Second, we have also considered the health costs related to the $PM_{2.5}$ precursor emissions on a much finer spatial resolution (5 x 5 km^2) than any previous corresponding study. A couple of previous studies have considered precursors (Muller and Mendehlson, 2009, Heo et al. 2016). However, both of the above mentioned studies addressed the U.S. as their modelling domain, Heo et al. (2016) on a resolution of tens of km. The resolution used in the study of Muller and Mendehlson (2009) was not reported, but considering their results suggests a resolution of tens of km. Air chemistry and the formation of particulate matter is strongly dependent on the chemical composition of the emitted pollutants and climatic factors; the above mentioned American studies can therefore not per se be generalized for European conditions. In addition, we have also allowed for the organic PM in our computations; this was not taken into account by Muller and Mendehlson (2009) or Heo et al. (2016).

Third, we have also programmed an internet-based computation tool, which is publicly available. We expect that this concept and the methods included within this easy-to-use tool would be useful also internationally.

Fourth, the manuscript includes a thorough, up-to-date literature review in this field (in the introductory section). Such a detailed review has not previously been presented in the literature. We have also reviewed in detail the current methods for evaluating the health impacts (in section 2.3) and economic impacts (section 2.4).

Although several public health cost studies with similar aims have been conducted in the U.S., reviewed European articles on health costs are much more scarce. Such studies will need to be done and published for several European regions, for various pollutants, and using different methodologies.

This is needed, as the relevant environmental conditions, such as air chemistry, population densities, the structure of emission source categories, the economic costs of life years, and many other relevant factors, are substantially different in various parts of Europe. The range of uncertainty in such estimates is also large, as shown also in the present study. For consolidating such estimates for various regions, pollutants, methods, etc., therefore requires that such evaluations will be presented for several European regions.

Referee's comment

An example for currently analysed improvements of the methodology is accounting for NO2 impacts, which the WHO now considers as likely, though less certain than PM2.5 impacts.

Authors' response

This is an interesting question, which we would like to elaborate in the revised manuscript.

Especially older diesel cars emit significant amounts of oxides of nitrogen. As diesel cars have become more common, there has been an intense debate about the need to curb NO_2 emissions in Europe. Long-term exposure to NO_2 has been associated with increased mortality in many epidemiological studies.

However, separation of the effects of NO_2 from the effects of particulate matter is challenging, due to their high correlation. Because of major uncertainties concerning concentration response functions, we did not include NO_2 in this study. WHO has also acknowledged that the effects of NO_2 are partly overlapping with $PM_{2.5}$ effects in epidemiological studies (WHO, 2013).

Referee's comment

Another issue is using exposure (i.e. concentration where people are) instead of concentration in the background, which would involve analysing also indoor sources (smoking, frying, wood heating).

Authors' response

We totally agree that this is an important new research direction. Part of the present authors have studied this matter by detailed modelling for Helsinki (e.g., Kousa et al., 2002, Soares et al., 2014, Kukkonen et al., 2016) and for London (Vikas et al, 2019). These studies have allowed also for the movements of the population in various micro-environments, and the infiltration of pollution to

indoor air. However, performing such modelling for an entire country would require a substantial amount of work. In our view, this could be a topic of another separate study.

Referee's comment

Another field is source apportionment to improve the large uncertainty of atmospheric modelling. In the text, a small chapter should at least mention current work on improving the methodology. A new part is the calculation of health impacts for emissions of different source groups like transport, residential a.s.o. Up to now, monetized health impacts have been estimated differentiated according to height of release and urban/nonurban area (see e.g. http://ecoweb.ier.uni-stuttgart.de/EcoSenseLE/current/index.php). Some important (now older, but still valid) guidelines for the methodology could be cited, e.g. the ExternE Externalities of Energy Methodology 2005 Update; downloadable at http://www.externe.info/externe_d7/?q=node/30 or the IEHIAS Integrated Environmental Health Impact Assessment System (2011); web based guidance system; accessible under www.integrated-assessment.eu .

Authors' response

Emission and atmospheric modelling in this study has been substantially improved, compared with previous studies, especially concerning the national very fine resolution emission inventory and the refinements of the SILAM model. These improvements could be elaborated in a revised manuscript.

We agree with the reviewer that a discussion and references on the EcoSenseLE and ExternE need to be added to the literature review and to the relevant sections in the text (e.g., Bickel and Friedrich, 2005). Clearly, these are important research methods and activities in this area, and certainly need to be referenced.

Referee's comment

The result is indeed useful for consultants or decision makers in Finland, that want to identify the most efficient measures for reducing health effects from fine particles. They may use the given unit cost figures for estimating the health benefit caused by reduced emissions, and could also use the tool provided. The editors should decide, whether the publication fits into the scope of their journal or whether a journal more oriented towards environmental policy application might be a better choice

Authors' response

In the authors' view, the paper would fit well to the scope of ACP.

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