Editorial

Thematic Issue on Modelling Human and Ecological Health Risks

Abstract

In this virtual thematic issue (VTI) the authors of 14 papers address key challenges of environmental modelling and software to support the identification of human and ecological health risks. The contributions address different pathways how environmental exposure can affect human health with a focus on models, data and software and can be divided into the following research areas: (1) modelling approaches to quantify air pollution concentrations and exposure, (2) models and methods to determine health effects of air pollution, (3) models and software to predict and quantify disease and health risks and (4) data interoperability and integration. These contributions highlight that further advances in this research field are required, especially from highly polluted regions, as so far papers from these regions are scarce. The majority of contributions covers exposure to ambient air pollution, which is a key public health risk in both industrialised and developing countries. While not a focus of this VTI, human exposure to water and soil contamination as well as exposure pathways through other environmental media are equally relevant. Further research into how modelling, software and data can support an integrated assessment of the whole *Exposome* is therefore essential.

1. Introduction

Health and the environment are intricately interlinked. As a consequence we see an urgent need to foster interdisciplinary and cross-domain aspects and integration in environmental modelling. This thematic issue focuses on how models and software play an important role in both identifying and – subsequently – quantifying the risks and effects of environmental pollution on human and ecological health. The release, transmission and environmental fate of pathogens and contaminants across environmental compartments are marked by complex processes - physical, chemical and biological. In the same way, exposure and effects on humans and ecosystems are the result of intricate interactions to – and often mixtures of – stressors that may affect health, biodiversity and ecosystem services. Models, closely linked with and driven by observations, are essential tools to understand the mechanisms, to account for the spatial and temporal variability across different scales, and ultimately to deliver robust evidence for decision makers. In addition, the way we communicate the results of our models, translate data into information and contribute to evidence-based decision making at the science-policy interface profoundly affects the usefulness and uptake of environmental model results in policy decision making. Last, but not least, there is growing demand for models to integrate across spatial and temporal scales as well as scientific and policy domains. Emerging concepts such as exposomics and ecological public health explicitly acknowledge the interaction between human activities, environmental determinants and (positive as well as negative) effects on the health of humans and ecosystems. With this thematic issue, we aim to contribute to this necessary integration. The papers contained in the thematic issue cover a variety of aspects, from atmospheric processes to health effects of air pollution, noise and water contamination. In addition, it addresses challenges of integrating modelling and sensor data for environmental and human health, highlighting current topics on human and environmental health risks from Australia, the United States of America and Europe.

2. Modelling approaches to quantify air pollution concentrations and exposure

Air pollution remains to be a major challenge for public health, with outdoor air pollution having been identified as one of the key drivers of adverse health effects on a global scale by Lim *et al.* (2012).

Dirgawati *et al.* (2015) have investigated health effects from long term exposure to air pollution in a cohort of 12,203 men aged 65 years and above, who were enrolled in the Health in Men Study (HIMS) in Perth, Western Australia. In their study, exposure to air pollution for each HIMS participant has been estimated using Land-Use Regression (LUR) models developed for the Perth Metropolitan Area for nitrogen dioxide (NO_2) and total oxides of nitrogen (NO_x). The study concluded, that land use variables, combined with local traffic sources explained a substantial proportion, of the spatial variability in average NO_2 and NO_x concentrations in Perth even at relatively low concentrations. This confirms that modelling approaches taking into account local data can provide statistically robust outputs, capture the predictors of NO_2 and NO_x spatial variability, and are feasible for use in predicting concentrations at every study subjects' location in population-based epidemiologic studies.

The development of a photochemical model to determine photochemical ozone creation potentials (POCPs), providing a tool to rank regional emission contributions of individual volatile organic compounds (VOCs) to tropospheric ozone formation is described by Lam et al. (2015). The results highlight the commonality of the VOCs identified between the Perth, Western Australia region, with much more highly polluted airsheds in different world regions. The use of the POCP concept and POCP-weighted emission ranking can help to identify key anthropogenic emitted VOCs that will most likely continue to be significant contributors to high ozone episodes. This study highlights a group of 27 alkane, alkene, aromatic and oxygenated VOCs, which show particular contributions to high ozone episodes in urbanized study locations from different regions around the globe.

Finally, a contribution by Maciejewska *et al.* (2015) focuses on statistical modelling of black carbon (BC) and its contribution to high pollution events in Poland. BC levels were measured at urban, suburban and regional background sites in Poland, with mean hourly concentrations ranging between 1,483 ng m^{-3} at a suburban site (Warsaw) in August and 3,947 ng m^{-3} at a regional site (Racibórz) during winter. Average levels of BC reported by this study were within ranges observed worldwide, but showed a strong influence from annual variations of emissions from residential fossil fuel combustion. The study further suggested that future air quality standards should include specific limit values for BC, as the statistical distribution identified in the paper allows to estimate the probability of occurrence and frequency of exceedances. This is of particular relevance for public health warnings when measurement data is scarce, as is the case in many countries and Europe and, even more so, in developing and emerging countries.

3. Models and methods to determine health effects of air pollution

As a next step in the modelling chain from ambient concentrations to air pollution effects on human health, models and methods to determine health outcomes from exposure are needed.

Kiesewetter *et al.* (2015) present a modelling approach utilising the GAINS[1] integrated assessment model to provide model forecasts of $PM_{2.5}$ concentrations for 1,875 individual air quality monitoring stations in Europe. In this study, premature mortality is calculated from anthropogenic $PM_{2.5}$ concentrations on a grid with a horizontal resolution of 7 km × 7 km. Based on this dataset, compliance with limit values is calculated from $PM_{2.5}$ concentrations at monitoring stations, based on a combination of bottom-up modelled fields and past observations. Their results indicate, that current emission control legislation implemented at European Union level will lead to a significant decrease of ambient $PM_{2.5}$ concentrations in comparison with past/present levels. By 2030, more than 98% of all stations would thus meet

[1] Greenhouse Gas - Air Pollution Interactions and Synergies, http://gains.iiasa.ac.at/models/

the current EU limit value for annual mean concentrations of $PM_{2.5}$ of 25 μg/m^3 annual mean concentration without any further political action.

In a similar approach based on the UK Integrated Assessment Model (UKIAM), Oxley *et al.* (2015) examine how different local authorities could potentially realise greater health benefits than implied by Kiesewetter *et al.* (2015). They focus in particular on emission abatement strategies targeting local sources emitting harmful particles such as black carbon (BC). The paper highlights the uncertainties in quantifying impacts of focussed air pollution abatement strategies upon human health, and provides some indication of the effect of uncertainties in epidemiologic findings related to black carbon or total mass of $PM_{2.5}$. This has implications for robust policy development, as it is advisable to take account of uncertainties about the toxicity of certain components by considering the reductions in concentrations of those components, as well as in total mass of $PM_{2.5}$. At the level of large urban agglomerations, temporal variations in pollutant concentrations and the mobility of residential and working populations exposed can make a significant difference in the estimated increases in life expectancy, which should be accounted for in future studies.

4. Models and software to predict and quantify disease and health risks

Software and models that can provide vital data to predict the location and severity of health risks can support planning of public health interventions. The paper by Liu *et al.* (2015) introduces the EASTWeb[2] software, which supports early warning systems for mosquito-borne diseases. EASTWeb has been integrated with the R environment to carry out modeling and mapping and has been extensively tested through applications to support mosquito-borne disease forecasting for West Nile virus in the United States and epidemic malaria in the highlands of Ethiopia.

Rajabi *et al.* (2015) present a spatially explicit agent-based modeling (ABM) approach for the spread of *Cutaneous Leishmaniasis* (CL) disease in central Iran, Isfahan. The results of this study revealed that the spatial situation of the main contact places between humans and CL vectors is the most important factor for exploring the spread of CL. This factor depends on the socio-ecological configuration of the landscapes in each region, and the physical and social characteristics of the environment in Isfahan province were simulated to explore the dynamics of these critical contacts using an ABM. Key results confirmed that availability of health centres could result in more protection against sand flies and more resistance against CL exposures when there is no possibility for restricting human activities spatially.

Human genetic radiation risks around nuclear facilities in Germany and five neighbouring countries were modelled by Scherb *et al.* (2016) in order to investigate differences in sex odds ratios (i.e. the probability distribution of children born with a specific gender). Sex ratio increases could be demonstrated near all selected nuclear facilities in France, Germany, and Switzerland by applying spatial and temporal models to approximately 63.4 million fully registered annual municipality-based births. According to descriptive and exploratory analyses, not only nuclear power plants in operation but also research reactors in operation and already dismantled nuclear reactors and nuclear power plants in neighbouring countries seem to have an impact on the human sex odds at birth.

Gulliver *et al.* (2015) describe the development of a model for assessing TRAffic Noise EXposure (TRANEX) in an open-source geographic information system (GIS). TRANEX has been developed so that it is transferable to other cities. In the UK this means that it can be applied in most areas as long as there is sufficiently detailed information on traffic

[2] Epidemiological Applications of Spatial Technologies

flows, composition and speeds. Overall, model estimates compared well to noise measurements (r: ~0.85–0.95) and noise level exposures were modelled for more than 8 million London residents for the period from 2003 to 2010. Results indicate, that over 1 million residents in Greater London are exposed to high daytime and night-time noise levels, which may lead to annoyance or sleep disturbance, affect the cognitive ability in schoolchildren and lead to health impacts, especially cardiovascular conditions and risk factors.

5. Data interoperability and integration

Software and data tools to facilitate the interoperability and integration of monitoring and modelling infrastructures are vital to translate data on environmental pressures into actionable information for decision makers.

Wiemann *et al.* (2016) introduce the design and development of a Spatial Data Infrastructure (SDI)-compliant online system for air quality information retrieval, including support for real-time monitoring. The resulting system assesses exposure to ambient air pollution to mitigate potential health risks, which is crucial for susceptible individuals, health practitioners and decision makers. The paper focuses on the development of an interoperable, applicable and transferrable approach to the application of robust and flexible air quality modeling as required for early warning systems on the Web. Key conclusions highlight the application of a number of validation methods to demonstrate the suitability of the approach, but identify as well further research needs in terms of the utilisation of geostatistical methods, such as Kriging. Future work should also focus, for instance, on implementing automated validation services for online information (to identify potential model failures) and better support the more general applicability of models in other domains as a central requirement for integrated environmental modeling (Laniak *et al.*, 2013).

The features and applicability of a software platform (πESA) designed for the optimization of Poland's power generation sector, simultaneously considering air pollution and health effects are presented by Wyrwa (2015). Results show, that the future energy mix in coal-based European Union countries, such as Poland, will be mostly influenced by carbon prices in Emission Trading Schemes (ETC), with higher prices favouring less carbon intensive options such as nuclear, renewables and gas power plants. An analysis of health impacts for the main scenarios revealed a reduction of statistical life expectancy in Poland by approximately 183 days, amounting to over 12 million life years lost for all population cohorts included in the analysis. However, this analysis revealed as well only marginal differences in health impact between the energy scenarios assessed.

Finally, Reis *et al.* (2015) discuss approaches and needs for a better integration of sensors and models to provide relevant actionable information for environmental and public health. The paper highlights how sensors and models need to play vital roles in harnessing 'Big Data' to extract information, and how data analytics can help to diminish monitoring burden and provide support in locating sensors. The exploration of 'Big Data' concepts is seen to be essential to detect universal associations across space and time, not only, but in particular in the case of environmental determinants of public health effects. With increasingly detailed and ubiquitous sensing, ethical challenges and issues of standards and harmonisation need to be addressed.

6. References

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