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A cost-efficiency and health benefit approach to improve urban air quality

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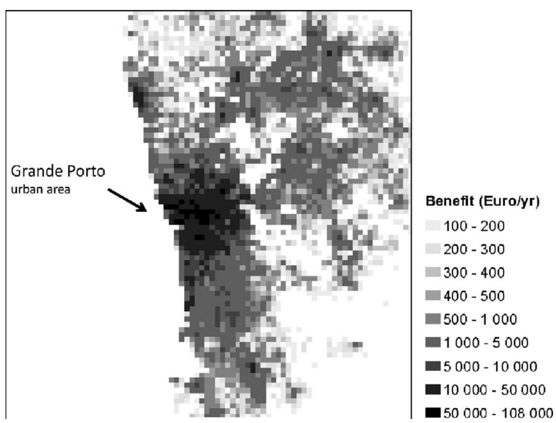
HIGHLIGHTS

- 4 abatement measures to reduce PM10 and NOx emissions characterized in terms of emissions and implementation costs
- Air quality and health impacts quantified by air quality modelling, cost-efficiency analysis and health impact functions
- The resulting scenario including all 4 measures lead to a total net benefit of 0.3 M €·y^{-1}.
- MAPLIA system is a useful tool for policy decision support for air quality improvement

GRAPHICAL ABSTRACT



An integrated assessment modelling system was applied to an urban area to assess the impacts of emission abatement measures, for PM10 and NO_2, on air quality and human health by means of a cost-benefit analysis. The largest contribution for health benefits derives from the reduction in PM10 concentrations in the Grande Porto municipalities.

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ABSTRACT

When ambient air quality standards established in the EU Directive 2008/50/EC are exceeded, Member States are obliged to develop and implement Air Quality Plans (AQP) to improve air quality and health. Notwithstanding the achievements in emission reductions and air quality improvement, additional efforts need to be undertaken to improve air quality in a sustainable way – i.e. through a cost-efficiency approach. This work was developed in the scope of the recently concluded MAPLIA project "Moving from Air Pollution to Local Integrated Assessment", and focuses on the definition and assessment of emission abatement measures and their associated costs, air quality and health impacts and benefits by means of air quality modelling tools, health impact functions and cost-efficiency analysis. The MAPLIA system was applied to the Grande Porto urban area (Portugal), addressing PM10 and NOx as the most important pollutants in the region. Four different measures to reduce PM10 and NOx emissions were defined and characterized in terms of emissions and implementation costs, and combined into 15 emission scenarios, simulated by the TAPM air quality modelling tool. Air pollutant concentration fields were then used to estimate health benefits in terms of avoided costs (external costs), using dose-response health impact functions. Results revealed that, among the 15 scenarios analysed, the scenario including all 4 measures

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lead to a total net benefit of 0.3 M €·y^{-1}. The largest net benefit is obtained for the scenario considering the conversion of 50% of open fire places into heat recovery wood stoves. Although the implementation costs of this measure are high, the benefits outweigh the costs. Research outcomes confirm that the MAPLIA system is useful for policy decision support on air quality improvement strategies, and could be applied to other urban areas where AQP need to be implemented and monitored.

1. Introduction

Nowadays, poor air quality is recognized as one of the most pressing problems in urban areas with very harmful impacts on health and the environment (EEA, 2015). Moreover, the World Health Organization (WHO) has recently classified air pollution as carcinogenic to human beings (WHO, 2013a). According to the latest report on air quality in Europe (EEA, 2015), air pollution implications are mainly due to high levels of particulate matter (PM) and ozone (O_3) in the atmosphere. Anthropogenic emissions are identified as the greatest contributors to air pollutant concentrations, but atmospheric phenomena occurring at different spatial scales also contribute to the increase in environmental damages.

In order to reduce air pollution effects, particularly in cities where the majority of the European population lives, it is important to define effective plans for air quality improvement. For this purpose, Air Quality Plans (AQP) establishing emission abatement measures, previously known as Plans and Programmes, have to be designed and implemented by the Member States (MS) of the European Union (EU) in accordance to the Framework Directive 96/62/EC on ambient air quality assessment and management, whenever in their zones and agglomerations the pollutant concentrations in ambient air exceed the relevant air quality limit values. In 2008, based on the Framework Directive and in other previously existing legal documents, a new Air Quality Directive (AQD) (Directive 2008/50/EC) was published, introducing new concepts, and simplified and reorganized guidelines. The application of numerical models is highlighted in this new Directive as a fundamental tool to better assess and manage air quality, encouraging their use in the preparation of AQP. These models must be used in combination with monitoring in a range of applications, as observed values are crucial for validation of these modelling approaches.

In most European MS the modelling tools used in AQP consider processes directly influencing air quality, from the emission to dispersion and deposition of air pollutants, but do not include, for example, exposure or indicators related to health (Miranda et al., 2015). Together with air quality assessment, quantifying the impact of air pollution on the public's health is a critical component for the design and evaluation of effective local and regional AQP (Costa et al., 2014), although not directly required by legislation. Indeed, several scientific findings show that current levels of air pollutants observed in European cities are associated with health risks, such as, cardiovascular diseases and lung cancer (Brook et al., 2004; Loomis et al., 2013; WHO, 2013a). Health impact assessments provide an objective estimate of the influence of mitigation measures on air quality and population health. It uses available epidemiological studies together with routine environmental and health data to evaluate the potential effects of a policy, programme or project on the health of a population, including how those effects are distributed across the population – thus helping decision makers to plan and implement measures to protect public health more effectively. When economic values are applied to these health endpoints, the monetary costs and benefits of different options can also be compared directly (O'Connell and Hurley, 2009).

The risk of developing a disease due to exposure to agents with different levels of intensity and duration can be assessed using a statistical model and corresponding exposure-response functions (ERF) (Smith et al., 1999). In the case of AQ, an ERF links the concentration of pollutants to which a population is exposed with the number of health events occurring in that population. They may be reported as a relative risk of a certain health response for a given change in exposure or as a slope from a linear regression model between the exposure and the risk of a certain health response. It should be noted that health effects can occur within a short period after exposure (short-term exposure) resulting in acute effects, or as a cumulative exposure over a longer period of time (long-term exposure) expressed as chronic effects. The appropriate selection of adverse health outcomes and ERFs is a critical step. The findings of epidemiological studies provide the scientific basis for these decisions. Thus, the impact is determined by the relation of two variables: exposure and effect. One or more indicators are used to express the change in population health status due to exposure to an air pollutant (stressor); most health-based indicators are or derive from mortality and morbidity endpoints.

Regarding the health impacts arising from air pollution, the following aspects in epidemiological studies are considered: (i) involved pollutants and their air concentration levels; (ii) health indicators analysed in terms of morbidity and mortality; (iii) affected age groups; and (iv) exposure time. These data are used to quantify the extent of these impacts evaluated through ERF and health outcome frequencies which, combined with the population exposure to air pollution changes after the implementation of air quality improvement measures, provides the number of attributable cases/days per health indicator (Eq. (1)) (EC, 2005).

$$\Delta R_i = I_{ref} \times CRF_{i,p} \times \Delta C_p \times pop \quad (1)$$

where:

ΔR_i – Response as a function of the number of unfavourable implications (cases, days or episodes) over all health indicators ($i = 1, \ldots, n$) avoided or not;
I_{ref} – Baseline morbidity/mortality annual rate (%);
$CRF_{i,p}$ – Correlation coefficient between the pollutant p's concentration variation and the probability of experiencing or avoiding a specific health indicator i (%, i.e. Relative Risk RR associated to a concentration change of 1 μg·m^{-3});
$\Delta;_p$ – Change in the pollutant p's concentration (μg·m^{-3}) after the adoption of abatement measures (emission scenarios); and
pop – Population units per age group exposed to pollutant p.

ERF values are usually derived from epidemiological studies due to absence of specific information on exposure-response relationships for the target area/population under study. Therefore, it is recommend selecting reference and up-to-date ERF preferably from an authoritative and influential institute or organisation (INTARESE, 2007). Usually the ERF used to calculate the response to pollutants exposure in Europe are from well-known USA studies (e.g. Harvard Six Cities study). However European cohort studies have also shown results consistent with a causal link between long-term air pollution exposure and mortality in Europe (Gehring et al., 2006; Raaschou-Nielsen et al., 2013). WHO has recently published a set of recommendations for ERF and cost-benefit analysis of key pollutants in support of the European Union's air quality policy revision (WHO, 2013b), where ERF and related background information for several mortality and morbidity effects associated with short and long-term exposure to particular air pollutants, such as particulate matter (PM), ozone (O_3) and nitrogen dioxide (NO_2), are provided.

Health impacts need to be translated into monetary values (i.e. external costs), in order to be properly considered as economic costs.