ENVIRONMENTAL SCIENCE & POLICY 44 (2014) 39–50

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/envsci

An environmental, economical and socio-political analysis of a variety of urban air-pollution reduction policies for primary PM10 and NO_x: The case study of the Province of Milan (Northern Italy)

M. Chiesa [a,*], M.G. Perrone [b], N. Cusumano [c], L. Ferrero [b], G. Sangiorgi [b], E. Bolzacchini [b], A. Lorenzoni [c], A. Ballarin Denti [a]

[a] Università Cattolica del Sacro Cuore, DMF, Via Musei 41, 25121 Brescia, Italy
[b] Università di Milano-Bicocca, Dipartimento di Scienze dell'Ambiente, del Territorio e della Terra, Piazza della Scienza 1, 20126 Milan, Italy
[c] Università Bocconi, IEFE, Via Roentgen 1, 20136 Milan, Italy

ARTICLE INFO

Keywords:
Primary PM10 emissions
NO_x emissions
Transport sector
Residential sector
Environmental cost–benefit analysis

ABSTRACT

In the frame of urban air-pollution reduction policies, economic costs and environmental benefits of a variety of actions have been quantitatively assessed for the Province of Milan (Northern Italy), focusing on PM10 and NO_x emission sources.

Short-to-mid-term interventions that have been taken into consideration include reduction of inner temperature in residential buildings, banning of residential biomass heating systems, banning of diesel fuelled domestic boilers, night-time streets washing, speed limit reduction on highways, circulation restrictions of oldest EURO vehicles, conversion of diesel buses to natural gas, car sharing/biking promotion, DPF adoption in diesel vehicles, extension of road lanes for urban buses, energy efficiency refurbishment in residential buildings.

Re*sults emerged from the cost–benefit analysis integrated with socio-political indicators obtained through direct surveys, will contribute, with an holistic and multidisciplinary approach, to drive the local administrators to implement the most suitable actions in one of the most polluted areas in west-Europe.

1. Introduction

Atmospheric pollution in highly anthropized and populated areas is widely recognized as a serious problem that may lead to severe health effects to population (WHO, 2013). Particulate matter (PM) and NO_x are among the atmospheric pollutants of major harm in many urban areas.

Milan, which is the main city in Northern Italy, is subject to very critical atmospheric pollution conditions for both PM and NO_x. In Milan the annually averaged concentration of PM10 (the regulated fraction of PM, comprehensive of particles with an aerodynamic diameter less than 10 μm) and NO_x in the last four years (2009–2012) were 45 $\mu g\,m^{-3}$ and more than 50 $\mu g\,m^{-3}$ respectively (ARPA Lombardia, 2012), above the

* Corresponding author.
E-mail address: maria.chiesa@unicatt.it (M. Chiesa).
http://dx.doi.org/10.1016/j.envsci.2014.07.012
1462-9011/

yearly EU limit value for the protection of human health of 40 $\mu g\,m^{-3}$ for both PM10 and NO_2 (2008/50/EC).

It is important to underline that, according to the same European Directive (2008/50/EC) for NO_x a yearly critical value of 30 $\mu g\,m^{-3}$ is foreseen for the protection of vegetation and ecosystems. While critical levels are fixed on the basis of scientifical knowledge about possible effects only on vegetation and ecosystems, limit values are stated in order to prevent harmful effects on both human health and ecosystems. Bad air quality in Milan is enhanced by adverse meteorological conditions, mainly in winter, with low dispersion factor that favors accumulation processes of pollutants at sites in the Northern Italy basin (Ferrero et al., 2011).

The contribution to concentrations of pollutants in Milan comes from several primary emission sources. Source apportionment studies have estimated the contribution of primary emissions sources influencing the air quality levels in Milan, by distinguishing the relative contribution of primary emissions which are local (set in the urban area) or not (coming from the widespread regional sources). If the wider Milan metropolitan area (including the city and its urbanized surroundings) is taken into consideration, the PM emitted locally results the major contribution (over 50%) of the annual mean primary PM10 concentrations in Milan (Bedogni and Pirovano, 2011). The estimated contribution of local emissions to annual mean NO_x concentration in Milan is even higher (80–90%) (ENEA, 2012). This means that, despite of the different regional sources contribution, the local PM and NO_x primary emission sources within the Milan metropolitan area are an important burden to air quality in Milan. Thus undoubtedly the definition of effective policies to reduce primary emissions of PM10 and NO_x over the Milan metropolitan area are a challenging task.

In this study we focus on the Milan metropolitan area corresponding to the administrative boundaries of the Province of Milan, represented by 134 Municipalities.

From the Regional Emissions database, the Inventory of Emission in AiR (INEMAR, 2010), it emerges that in the Province of Milan residential combustion and transport on road are the macro-sectors that show the most relevant contributions in terms of annual emissions of both primary PM10 and NO_x. According to the most recent INEMAR database for the year 2010 (INEMAR, 2010), the residential sector covers about 24% of primary PM10 emissions in the Province of Milan, while the transport on road sector (direct emissions) about 58%. Even considering NO_x emissions, the annual contributions of the residential and transport on road sectors with respect to total emissions in the Province of Milan amount to about 12% and 71% respectively. The other emission sources (with particular reference to industrial processes, agricultural practices, wastes management, ...) are less or not relevant.

In this work we performed calculations for the primary PM10 and NO_x emissions in the Province of Milan from the two macro-sectors, traffic and residential heating, by considering the reference year 2010 and projecting the emissions to 2015. While the Regional INEMAR database only estimates the direct traffic source, in this study we considered for traffic both the direct and indirect (resuspension of road dust) PM10 emissions (Section 2.2.1). Various studies report that among several European cities a large part (50% and more depending on the location) of the total traffic PM10 emissions can originate from the indirect traffic source (Amato et al., 2010; Bukowiecki et al., 2010; Ketzel et al., 2007).

The most innovative aspect of this study concerns the analysis, by a multidisciplinary approach, of a wide portfolio of both emergency and structural (to be deployed in the short-to-medium term, respectively) actions aimed to reduce primary emissions of PM10 and NO_x due to both traffic and residential heating sectors in the Province of Milan. We evaluated the environmental effectiveness associated to several actions which could be undertaken in the area of the Province of Milan, estimated as the annual emissions abatement (expressed in tons year^{-1}; t y^{-1}). Along with the environmental outcome, for each measure we estimated the direct economic costs (expressed in million euro year^{-1}; M€ y^{-1}) supported by both public authorities and private citizens to identify a "priority list" in terms of environmental effectiveness and economic efficiency. Moreover, environmental and economic data have been integrated with social and political data concerning the effectiveness perceived and the real policy implementation degree for each action considered.

To our knowledge no other studies exist that combine environmental, economic, social and political evaluations to analyse so many atmospheric policies, in both transport on road and residential sectors, that could be applied to the Milan metropolitan critical area. Also this work shows a holistic, multidisciplinary approach that can be exported to other urban areas worldwide for the assessment of different pollution abatement strategies.

2. Materials and methods

2.1. Description of emission reduction actions

Up to 15 reduction actions in the transport (10) and residential heating (5) sectors have been analysed in terms of environmental benefits and direct economic costs associated to their application in the Milan metropolitan area.

With regard to the transports sector, the proposed actions have been grouped under four different areas, namely: sustainable public transports, private mobility, DPF installation on diesel vehicles and PM10 resuspension. In Table 1 we report the list of the specific actions that have been envisaged and their belonging sector/area.

Each action is classified as emergency (EA), short term, or structural (SA), medium term, action.

For each action we have considered a certain implementation level (scenario). Each scenario corresponds to a certain degree of action implementation, and the estimation of both environmental impacts and costs of an action necessarily depends on the specific scenario considered, as also reported in Table 1. For each action the most "realistic" scenario was defined by taking into account previous studies and data, when existing, for the specific area of Milan and/or other literature studies. The Province of Milan, which commissioned the study, collaborated in recovering local information and data for Milan, which were also useful in hypothesizing the scenarios of action implementation. For some actions (four actions: A2, A4, A7 and A10) a unique scenario has been