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An integrated assessment of two decades of air pollution policy making in Spain: Impacts, costs and improvements

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HIGHLIGHTS

- The effect of air pollution policy making in Spain is studied between 2000 and 2020.
- An integrated assessment (IA) model for Spain was used (AERIS).
- Decreases in non-complaint zones with EU NO_2 and PM_{10} limit values were seen.
- Policy making decreased the impacts on human health, ecosystems and soils.
- Reductions in damage and health-related costs were observed in the studied years.

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ABSTRACT

This paper analyses the effects of policy making for air pollution abatement in Spain between 2000 and 2020 under an integrated assessment approach with the AERIS model for number of pollutants (NO_x/NO_2, $PM_{10}/PM_{2.5}$, O_3, SO_2, NH_3 and VOC). The analysis of the effects of air pollution focused on different aspects: compliance with the European limit values of Directive 2008/50/EC for NO_2 and PM_{10} for the Spanish air quality management areas; the evaluation of impacts caused by the deposition of atmospheric sulphur and nitrogen on ecosystems; the exceedance of critical levels of NO_2 and SO_2 in forest areas; the analysis of O_3-induced crop damage for grapes, maize, potato, rice, tobacco, tomato, watermelon and wheat; health impacts caused by human exposure to O_3 and $PM_{2.5}$; and costs on society due to crop losses (O_3), disability-related absence of work staff and damage to buildings and public property due to soot-related soiling ($PM_{2.5}$). In general, air quality policy making has delivered improvements in air quality levels throughout Spain and has mitigated the severity of the impacts on ecosystems, health and vegetation in 2020 as target year. The findings of this work constitute an appropriate diagnosis for identifying improvement potentials for further mitigation for policy makers and stakeholders in Spain.

1. Introduction

Since the adoption in 1999 of the Gothenburg Protocol to abate acidification, eutrophication and ground-level ozone, the Government of Spain has been continuously designing and implementing regulations to abate general air pollution level and comply with its international obligations as a signing party. Moreover, as a Member State of the European Union, Spain is legally-bound by the European regulatory framework on air and environmental quality which has required complementary policy efforts across several years. In general the policy making process for air quality control in Spain has not been a simple one, too often conditioned by conflicts between national and regional governments in the distribution of competencies. As a result, a complete and sensible analysis of the effects of these policies not only on emissions or air quality levels, but on crucial variables such as human health, protection of ecosystems and associated costs has been absent for many years. In 2011, a scientific task force headed by the Centre for Integrated Assessment Modelling (CIAM) conducted a revision of the Gothenburg Protocol using IIASA's Greenhouse gas–Air pollution Interactions and Synergies (GAINS) model (TSAP Report #11). The results of this study revealed improvements in the general air quality picture in the Spain (as in Europe) but required establishing new reduction commitments for 2020 (Amann et al., 2012).

In line with these findings, the general perception among stakeholders and public opinion is that the air quality in Spain has improved but that there is still sufficient clearance for further action. An example of this is that in 2012, Spain was still facing difficulties in complying

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with the European limit values for annual nitrogen dioxide (NO_2) concentrations in 4 air quality management zones, particulate matter (PM_{10}) daily levels in 11 zones and ground-level ozone (O_3) above target value in 51 zones (Orío et al., 2013). The purpose of this study is to evaluate the impacts and benefits of the general air quality policy making process in Spain between the adoption of the Gothenburg Protocol and the target year for the new reduction commitments in 2020. The ultimate goal is to quantify the global improvement on the air quality question in Spain in order to provide enough guidance on the effectiveness of the measures that were undertaken and those that are still to be enforced towards the 2020 target year.

This analysis will be conducted following an integrated assessment (IA) approach, due to the fact that it focuses on holistic modelling perspectives that are able to generate relevant information for environmental planning without the need to configure complex atmospheric dispersion models under long run times (Moussiopoulos et al., 2009; Oxley et al., 2013). Relying in IA allows quantifying the most relevant effects that air quality has on human and environmental health for both past and future scenarios. For the concrete case of this study, this analysis was made using the newly-embedded modules for the quantification of air quality impacts and costs of the Atmospheric Evaluation and Research Integrated system for Spain (AERIS), combining diagnostic (past years) and prognostic (future years) approaches (Vedrenne et al., 2014a). Besides assessing compliance with the European Limit Values (LVs) for nitrogen dioxide (NO_2) and particulate matter (PM_{10}), the analysis focused on evaluating the consequences of air pollution such as damage on ecosystems and human health, as well as estimating the economic benefits of policy-driven action.

2. Methodology

As already stated in the introduction, the evaluation of the air quality control policies undertaken by the different Spanish administrations in the two decades comprised between 2000 and 2020 was carried out following the integrated assessment approach of the AERIS model. This section is devoted to explaining the origin and preparation of the necessary input data for running the model as well as outlining the methodologies and criteria for the estimation of impacts and economic benefits, recently incorporated in AERIS.

2.1. Scenario definition

The policy making activity for air quality control in Spain between 2000 and 2020 was modelled as a set of 11 biannual scenarios that contemplate a series of concrete control measures resulting in emission reductions for 5 pollutants considered by AERIS: nitrogen oxides (NO_x), sulphur dioxide (SO_2), ammonia (NH_3), particulate matter (PM_{10}, $PM_{2.5}$) and volatile organic compounds (VOC). For the years comprised between 2000 and 2012, emission scenarios were derived from officially reported emission data as well as the concrete control strategies that limited these emissions. To be consistent with the conceptual formulation of AERIS, annual emission data for these years and the before mentioned pollutants were obtained from the Spanish National Emission Inventory (SNEI) disaggregated by SNAP activity code (MAGRAMA, 2014). The future character of the period between 2014 and 2020 made necessary to rely on emission projections which in the case of AERIS are to be quantified with the Spain's Emission Projection (SEP) model (Lumbreras et al., 2008). These projections were estimated for each of the pollutants mentioned above, considering only a situation defined by the current legislation (CLE) in order to analyse the effectiveness of the implemented plans, measures and policies in Spain. Additional considerations regarding the nature and potential evolution of the macroeconomic drivers of the projections, specifically those concerning the latest economic crisis in southern Europe were implemented according to what has been published in MARM (2009) and Torrero (2010). The aggregated national emissions (without SNAP sector distinction) of the studied pollutants across the studied years are presented in Table 1 and Fig. 1.

2.2. Control measures

In general, strategic management of atmospheric pollution through policy should be translated into a specific set of control measures that have to be realistic and applicable for a concrete target activity (Vlachokostas et al., 2011). To this respect, a number of actions and measures were identified from the different national air quality management plans that have been implemented in Spain in the past years and that are deemed responsible for the experienced trend in the national air quality situation. For the future years, it was considered that CLE prevails and that no extraordinary actions to tackle air pollution will take place. For the purposes of this study, the CLE situation in Spain is the one defined by Directive 2008/50/EC and its respective transposition to the national regulatory framework through the Royal Decree 102/2011 and Law 34/2007 (Orío et al., 2013). The concrete measures that were identified are shown in Table 2, and classified as technical (TM) and non-technical measures (NTM) following the end-of-pipe criterion established in the GAINS modelling framework (Schucht, 2005). Due to the difficulty associated with the allocation of a reduction percentage to NTM, these were not considered for the projection of emission scenarios (D'Elia et al., 2009). The selected TM were differentiated by the administrative level that applied them (national, regional and local) according to the information submitted by Spain to the European Commission (Questionnaire 461 on Directive 1999/30/EC).

2.3. Atmospheric dispersion

In order to estimate the effects of air pollution, it is necessary to quantify the concentration levels resulting from atmospheric dispersion and chemical processes across a given domain. To this respect, the IA approach followed by AERIS allows quantifying final pollutant concentration (NO_2, SO_2, NH_3, PM_{10} and $PM_{2.5}$) through a series of transfer matrices for individual SNAP sectors as a function of a baseline scenario of emissions (in this case, the emissions reported by the 2007 version of SNEI). These transfer matrices constitute a parameterisation of the WRF-CMAQ air quality modelling system configured for Spain as described in Borge et al. (2014) and allow retrieving concentration values for 4500 16 km-cells deployed in a 75 × 60 grid centred in 40°N and 3°W which covers the entire Iberian Peninsula and parts of the neighbouring countries (Vedrenne et al., 2014a). The effects of tropospheric ozone (O_3) or the secondary fraction of particles are accounted for in AERIS through a secondary pollutant module that relates them

Table 1
Aggregated annual emissions of the studied pollutants in Spain across the studied years — (annual metric tons per year).

Pollutant	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020
NO_x	1,415,399	1,424,453	1,456,473	1,415,782	1,213,378	1,022,917	1,043,164	1,063,994	1,039,300	1,048,280	1,063,324
SO_2	1,616,057	1,591,735	1,377,336	1,219,739	565,916	489,434	470,181	468,127	466,069	480,273	492,815
NH_3	405,271	398,997	404,289	404,031	371,952	395,139	372,996	379,879	387,211	395,019	403,330
$PM_{2.5}$	97,764	97,109	96,074	91,993	84,745	77,173	72,302	69,521	68,655	67,884	67,238
VOC	2,413,546	2,240,359	2,286,084	2,225,590	2,014,611	1,923,981	1,090,067	1,102,374	1,119,143	1,139,234	1,164,867