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Human Health Risk Assessment and Action Plans for PM10 Pollution: a new integrated methodology for Campania Region (Italy)

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Abstract Air pollution is a global issue with harmful effects on both human health and the environment. According to the World Health Organization (WHO), air pollution causes approximately 7 million premature deaths each year, primarily due to respiratory and cardiovascular diseases. The study presents and discusses a project named ARIA ("Risk Analysis and Action Plans for PM10 Pollution in the Campania Region"). ARIA project addresses the critical issue of PM10 air pollution and its health impacts in the Campania Region (Southern Italy), a territory characterized by dense urbanization. Funded through a regional program in collaboration with MASE (Italian Ministry of Environment and Energy Security), the project aims to assess population exposure to PM10, estimate associated health risks, and develop evidence-based mitigation strategies. To this end, a novel integrated methodology has been developed to implement a multidisciplinary approach, integrating demographic vulnerability analysis, emission estimation, air dispersion modeling, and health risk assessment following WHO guidelines. Emissions from key sources, including industry, traffic, residential heating, and agriculture, have been spatially allocated using a 1 km² grid. The CALPUFF and CALINE models have been implemented for the simulation of pollutants dispersion, while in-field measurements supported model validation. Health risks was evaluated in terms of premature mortality and years of life lost (YOLL), based on population data, mortality rates, and estimated pollutant concentrations. The city of Salerno was selected as a pilot site for methodology validation.

Keywords: air pollution, risk analysis, urban environment, dispersion modelling, emissions inventories.

1. Introduction

Air pollution remains one of the most pressing environmental and public health challenges. According to World Health Organization (WHO), exposure to air pollutants is responsible for approximately 7 million premature deaths annually, predominantly due to respiratory and cardiovascular diseases (WHO, 2024). Among the various atmospheric pollutants, particulate matter, most notably particles with an aerodynamic diameter less than 10 micrometers (PM10), has been extensively linked to increased rates of hospital admissions, morbidity, and mortality (Seihei et al., 2024). The fine nature of PM10 allows it to penetrate deep into the respiratory tract, exacerbating existing conditions such as asthma and bronchitis, and contributing to the development of chronic obstructive pulmonary disease (COPD), ischemic heart disease, and stroke (Alexeeff et al., 2021). The issue is particularly severe in regions characterized by high population density, intense anthropogenic activity, and unfavorable meteorological and orographic conditions (Meirelles and Vasconcelos, 2025). Some area of Campania Region, located in Southern Italy, are characterized by highly dense urban and industrial settlements, in some cases coupled with poor dispersion conditions, resulting in episodes of elevated PM10 concentrations for the exposed population with possible health risks to local communities (Oliva et al., 2024). To address this topic, the study presents and discusses a project named ARIA ("Risk Analysis and Action Plans for PM10 Pollution in the Campania Region"), aiming at devoloping an integrated methodology for estimating the main sources of PM10 in the study area, assessing human exposure to PM10, estimating health risks, and supporting the formulation of targeted air quality improvement strategies. Funded under a joint program between the Campania Regional Authority and the Italian Ministry of Environment and Energy Security (MASE), the project is grounded in a multidisciplinary framework that integrates environmental engineering, atmospheric science, and public health. To this end, the methodology has been developed in multiple layers: (i) Demographic Analysis and Assessment of Population Vulnerability; (ii) Estimation of Emissions, (iii) Estimation of Ground-Level Concentration at point of exposure; (iv) Health Risk Assessment. By leveraging high-resolution spatial data,

field measurements, and dynamic modeling approaches, the ARIA project provides a replicable and scalable methodology for air quality management in complex urban and industrial territories. The city of Salerno was selected as a pilot area for the application and validation of the proposed framework, enabling the project to deliver actionable insights for both local implementation and broader regional adaptation. A key innovation of the project lies in the creation of a predictive and proactive decision-support tool, designed to assist policymakers in prioritizing interventions and protecting vulnerable populations.

2. Materials and methods

The demographic analysis and the assessment of population vulnerability rely on the integration of multiple datasets, including census tract maps, population counts by census tract, age distribution of the population by census tract, age-specific incidence of chronic and oncological diseases, land use map (CORINE Land Cover). The estimation of emissions was conducted focusing exclusively on the quantification of primary anthropogenic emissions, excluding natural sources, secondary particle formation, and resuspension of settled dust. Four main categories of anthropogenic sources are considered: (i) transport (road, port, and airport); (ii) residential heating; (iii) industrial activities; (iv) agriculture. Emission sources are spatially disaggregated and classified based on their typology, spatially allocated using a 1 km² grid. Industrial facilities have been modelled as point sources, residential heating, urban road traffic, port and airport activities have been modelled as area sources while extra-urban road traffic have been modelled as line sources. CALPUFF modeling system was employed for the simulation of atmospheric dispersion from point and area sources while linear sourced were modelled by CALINE, specifically designed to assess the impact of vehicular traffic on sensitive areas near major roadways. For each grid cell of the domain, the maximum concentration value calculated within that cell, resulting from the overlapping of the outputs of the models, was assigned. For the health risk assessment, the approach adopted by the European Environment Agency (EEA) was used, whereby mortality is considered the primary indicator for evaluating health risks, as it represents the most severe outcome of air pollution and the one supported by the strongest scientific evidence (EEA, 2025). Results were calculated as Relative Risk (RR) and Years of Life Lost (YOLL).

Results

The Municipality of Salerno was selected as the study area for the application of the methodology due to its peculiar orographic and weather-dispersive characteristics. These notably complex conditions provide a particularly suitable context for validating the proposed methodology, allowing its effectiveness to be tested even in challenging meteorological and dispersive scenarios. The proposed methodology has been applied for estimating the PM10 emissions in the territory of interest. The estimated emissions for Salerno municipality in terms of residential heating (RH) and urban road traffic (URT) are reported as grid PM10 emissions in Figure 1. The spatial distribution of emission from these two sources are quite similar to the spatial distribution of population density. These emissions are estimated for their usage as input in dispersion model for the calculation of the concentration at the point of exposure. In this way, the concentrations calculated by the model are assigned to the locally corresponding exposed population for the assessment of the human health risk in terms of morality and reduction of years of life. The outputs from the implementation of the methodology can be exploited for developing a decision-making support tool able to compare different scenarios of territory governance and for design strategic actions for increasing ambient air quality and reducing the associated risk for human health

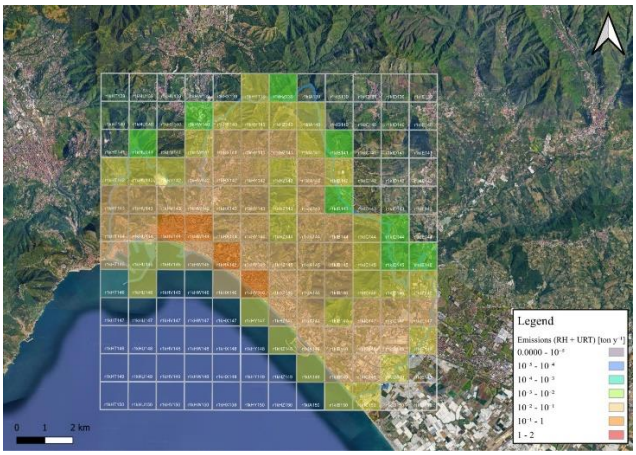

Figure 1 – PM10 emissions from residential heating and urban road traffic calculated per grid in Salerno municipality

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