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Towards a better protection of children's respiratory health against particulate matter pollution in urban areas – ROkidAIR project

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Abstract

Many recent evidences raised awareness for the Particulate Matter (PM) air pollution with fine (PM2.5), submicrometric (PM1) and ultrafine fractions (PM0.1) and its impact in urban areas, pointing out the adverse consequences on the wellbeing of children, particularly on the respiratory health. The health effects of PM can range from nausea and difficulty in breathing, to skin irritation and include birth defects, significant developmental delays in children, and reduced activity of the immune system, leading to a number of acute or chronic diseases. In this context, the rationale of the research aimed the protection of the children's health related to poor air quality in two cities of Romania i.e. Ploiesti and Targoviste by deploying a PM2.5 monitoring system as a component of an intelligent cyberinfrastructure, which is able to provide early warnings and forecasting of PM pollution episodes. A PM2.5 monitoring microstation prototype containing a measurement, a climate-conditioning, and a control/communication modules, was designed and developed in the ROkidAIR project. The measurement subassembly samples from the atmosphere a relevant air volume, with a controlled flow, filters the 2.5 μm fraction, reduces the humidity of intake air volume, passes the airflow through the PM2.5 optical transducer and measures the PM2.5 concentration level at predefined time intervals. Based on the prototype, an advanced PM2.5 monitoring network system comprising 8 microstations provide continuous PM2.5 data in view to be pre-processed and adapted as inputs in forecasting algorithms based on artificial intelligence techniques. The resulted cyberinfrastructure provides information to the end-user terminals quantifying and estimating children's exposure to airborne particulate matter for elaborating early warnings when significant pollution episodes occur.

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Keywords: cyberinfrastructure, PM2.5 monitoring, PM2.5 microstation, artificial intelligence, early warning system

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1. Introduction

Particulate matter (PM) is one of the major airborne pollutants in urban environments containing inhalable particles that penetrate the thoracic region of the respiratory system determining considerable negative health effects, which aggravates with the lower sizes of particles, exposure duration and people's vulnerability (children, older adults, people with chronic pulmonary and cardiopulmonary diseases, or with lower socioeconomic status).

(i) Exposure to high levels of PM may cause major adverse health effects on the population at or near air polluted sources;

(ii) According to WHO [1], and the latest epidemiological research, exposure to PM may have negative impacts on health including respiratory and cardiovascular morbidity i.e., aggravation of asthma, respiratory symptoms and an increase in hospital admissions, and mortality from cardiovascular and respiratory diseases and from lung cancer in adults;

The paper presents an on-line monitoring system for PM2.5 (fine particulates) developed in the ROkidAIR project, which uses self-designed microstations in fixed locations as well as complementary mobile applications to assess the personal exposure in specific urban microenvironments.

In the last years, many automated instruments for PM monitoring were developed to improve the precision of measurements and to allow online assessments. The authorities' interest to deploy continuous monitoring networks has considerably grown at global level. In his book *De Morbis Artificum Diatriba* (Diseases of Workers), one of the pioneers of the Occupational Medicine, Bernardino Ramazzini outlined early in 1700 the effect of inhalable particles on the health hazards associated with workers in 52 different occupations [2]. Since the simple microscope used by Ramazzini for particle counting, many improvements occurred in the field of particulate matter measurements. Starting from the widely used transmissometers (from 1968 to 1985), the technology has advanced to more modern analytical solutions used for continuous PM measurements based on the light scattering effect, absorption of beta radiation, the triboelectric effect and also direct measurements solutions like the tapered element oscillating microbalance (TEOM).

In practice, there are many technical solutions for estimating the concentration of suspended particles [3]. They can be classified according to the following criteria: equivalence with the reference methods, accuracy of the analysis, possibility for continuous measurement of particulate matter, possibility of automatic recalibration, estimation of chemical compounds in particles, ability to count particles and to classify them according to their diameter, system's portability, energetic autonomy, and data storage capacity.

The indicator for fine particles is measured using the Reference Method for the Determination of Fine Particulate Matter as $PM_{2.5}$ in the Atmosphere (appendix L to 40 CFR part 50), which is known as the $PM_{2.5}$ FRM [4]. An analysis of changes in PM measurement methods and air quality standards in US as compared to China is found in [5].

By exposed to respirable PM air pollution, children and elderly people are the most affected categories of population; exposure to fine and ultrafine PM affects lung development in children, including reversible deficits in lung function as well as chronically reduced lung growth rate and a deficit in long-term lung function [6,7]. Safe levels of exposure or a threshold below which no adverse health effects occur are difficult to be established [1,4].

Our previous results [8] support the hypothesis that increased outdoor $PM_{2.5}$ levels directly influence wheezing symptom and asthma attacks in children. Immunoglobulin E, eosinophils, and wheezing episodes may be considered key indicators with which to evaluate the adverse effects of PM2.5 air pollution on children's health.

The study presents the architecture of the monitoring system for particles with an aerodynamic diameter below 2.5 µm based on self-designed microstations that are using laser beams for measurements. The outdoor continuous monitoring of PM2.5 provide key information for the assessment of population's exposure, the planning of air quality and the establishing of reliable measures for the lowering of PM emission in critical urban microenvironments.

The specific objectives of the ROkidAIR project were to: (i) relate children's respiratory illness to fine particulate matter exposure (PM2.5); (ii) develop an early warning system to reduce citizens' exposure to high air pollution levels; and (iii) gather and refine knowledge to be used by the public and authorities to survey and plan the air quality.