ABSTRACT

Multimethodological research on air quality monitoring in urban microenvironments

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This doctoral thesis, in the format of "collection of scientific papers", synthesizes the results of seven original studies published and indexed in Web of Science, conducted in the peri-urban Timișoara–Dumbravița area along the DJ691 arterial road, with the aim of providing a multidimensional characterization of air quality in urban microenvironments subject to intense road traffic pressure.

The research employed a stratified instrumental approach: reference gravimetric cascade impactor sampling, scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM-EDS), continuous annual monitoring with low-cost sensors (Airly), predictive modelling via Random Forest algorithms, and measurements in university indoor spaces and inside a convertible vehicle under real urban traffic conditions.

Daily PM_{10} concentrations frequently exceeded the European limit of 50 µg/m³, reaching a maximum of 116.8 µg/m³. SEM-EDS analysis identified iron, silicon, calcium, and lead as principal markers of non-exhaust emissions — brake wear, road dust resuspension, and historical lead-contaminated soil deposits. Annual monitoring revealed a pronounced seasonal contrast in $PM_{2.5}$, with a winter-to-summer ratio of 3.1 driven by thermal inversions and residential biomass burning, and an inverse ozone profile peaking at 43.95 µg/m³ in summer.

The Random Forest model trained on Airly sensor data achieved $R^2 = 0.84$ for hourly $PM_{2.5}$ prediction, demonstrating the feasibility of gravimetrically validated low-cost sensor networks as a scalable alternative to costly reference instruments. In university spaces, CO_2 exceeded 3,000 ppm in lecture halls, and natural ventilation significantly reduced indoor PM levels (Cohen d > 0.8). Inside the open-roof convertible vehicle, PM_{10} reached 889.8 µg/m³ at the roadside and noise levels exceeded the WHO threshold of 53 dB(A) throughout the entire route.

Original contributions include the first systematic SEM-EDS chemical characterization of particles from DJ691, the first photovoltaic autonomous roadside monitoring system in the Timișoara metropolitan area, the first locally calibrated multi-pollutant Random Forest predictive model, and the first comparative assessment of occupant exposure in convertible versus enclosed vehicles under real traffic conditions in Romania.