Milestone M9 (M2.2, M2.4, M2.6)

Demonstration analyses daily air pollution and health, oxidative potential and urban mapping

RI-URBANS

Research Infrastructures Services Reinforcing Air Quality Monitoring Capacities in European Urban & Industrial AreaS (GA n. 101036245)

By

UU, UoB, ISGlobal, VITO and CNRS-IRD

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M9 (M2.2, M2.4, M2.6): Demonstration analyses daily air pollution and health, oxidative potential and urban mapping

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Work package (WP)	**WP2 Health effect assessment of PM, PM components, nanoparticles, and their source contributions**
Milestone	M9 (M2.2, M2.4, M2.6)
Lead beneficiary	UU
Means of verification	Demo-analyses completed for the three topics
Estimated delivery deadline	M36 (30/09/2024)
Actual delivery deadline	20/09/2024
Version	Final
Reviewed by	WP2 leaders
Accepted by	RI-URBANS Project Coordination Team
Comments	This document provides a short description of the Demonstration analyses daily air pollution and health, oxidative potential and urban mapping conducted within WP2

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1. About this document

This document summarises the milestone achieved with respect to Demonstration analyses of daily air pollution and health, oxidative potential and urban mapping. These analyses have been conducted in the framework of WP2. In WP2, T2.1 refers to the improved evaluation of health effects in epidemiologic time series studies. T2.2 refers to Evaluation of oxidative potential (OP). T2.3 refers to fine resolution urban mapping, including mobile monitoring of nanoparticles and citizen observatories to improve evaluation of health effects of long-term.

This is a public document, available at the RI-URBANS website, https://riurbans.eu/work-package-2/#milestones-wp2, and distributed to all RI-URBANS partners for their use as well as submitted to the European Commission as an RI-URBANS Milestone M9 (M2.2, M2.4, M2.6).

2. Scope

The scope of this M9 (M2.2, M2.4, M2.6). is to present a documentation of the achievement of the milestone of the analyses of daily air pollution and health, oxidative potential and urban mapping. We refer to specific Deliverables and output to provide detailed documentation.

3. Demonstration analyses daily air pollution and health

Task 2.1 produced a document with best practices for evaluating the association between short-term exposure to air pollution and health outcomes (mortality and morbidity) (D9 (D2.1)). The document included recommendations on the type of data needed, sources for the health data, common challenges of health data collection, and a summary of two types of analyses, time series analysis and health impact assessment. In addition, T2.1 conducted the compilation of health dataset for analysis, conducted data cleaning, merged health data with AQ data, prepared analysis codes and conducted analyses on the relationship between air quality metrics and mortality / morbidity, the main topic of this milestone report.

In total complete data for 12 cities were available for implementing studies on the short-term effects of UFP, fractions of PNSD and source contributions to PNC, and BC. Endpoints that we evaluated were mortality from all causes, mortality from cardiovascular disease and mortality from respiratory disease. The studies for short-term health outcomes were carried out by ISGlobal or in UK and Germany using the same algorithms due to health data restrictions out of the country. Novel air quality metrics that were assessed were PNC, UFP, Nucleation, Aitken and Accumulation mode independently, as well as daily source contributions (all these received from WP1), lung deposition surface area metrics, PM metrics, gases, black carbon and black carbon sources. Analyses included examinations of all lags up to lag 7, examination of city-specific results and meta-analysis of results from all cities, examination of two-pollutant models, and interactions of pollutants with heat waves. The team is now processing and describing the huge amount of results produced, which will be included in Deliverable D10 (D2.2).

Figure 1 shows an advancement of the results that will be included in D10 (D2.2). Results show an increase in risk of natural mortality at lag 5 associated with the nucleation mode; and increases in risk of cardiovascular mortality associated with Aitken, UFP, Ntotal and accumulation modes at lag 5, and some at lag 6.

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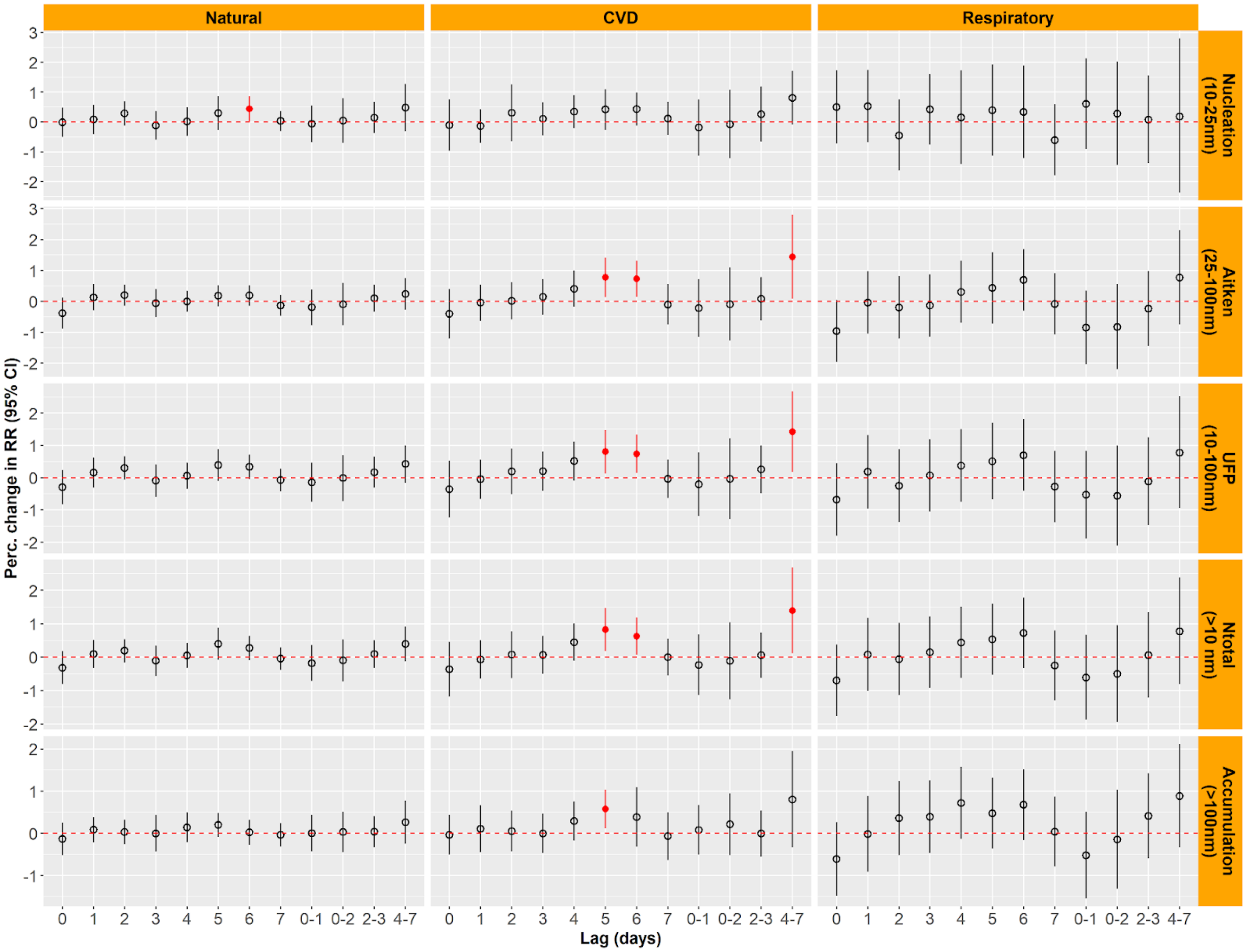

Figure 1: *Associations (percent change and 95% confidence intervals) between mortality and the different PNSD modes, according to lag, in single-pollutant models. Results were obtained via meta-analysis of the city-specific results.*

4. Demonstration analyses oxidative potential

In task 2.2 the launched laboratory inter-comparison of oxidative potential was carried out. This study is a substantial collaborative endeavour, combining the outcomes of the first-ever interlaboratory comparison (ILC) exercise of its nature. The ILC, which included the participation of 20 laboratories globally, was intended to evaluate the measurement of oxidative potential (OP). The primary objective was to pinpoint any potential inconsistencies in the results derived from the OP DTT assay, a widely used acellular assay for OP measurement. Our ILC also aimed to to assess the consistency of OP measurements between participants that apply different OP DTT protocols, since OP has been proposed and recommended as a parameter to be measured in the proposal for a new European Air Quality Directive (Council of the European Union, 2024).

Our results emphasise both the strengths and challenges associated with the use of the current OP DTT assay for driving a measurement of PM OP. In summary, half of the participants attained results that were within an acceptable range of z-scores for this test (Figure 2). While notable agreement was observed in certain samples and between several groups, discrepancies and variability were also identified, underscoring the necessity for

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standardisation in the procedures and conditions. This pioneering work concludes that interlaboratory comparisons provide essential insights into the OP metric and are crucial to move toward the harmonisation of OP measurements. We have now a RI-URBANS OP^{DTT} protocol to propose and we would like to add a new round robin laboratory exercise to go deeper and to test OP^{AA} and that we are searching for external support and require some minor changes of budget among partners.

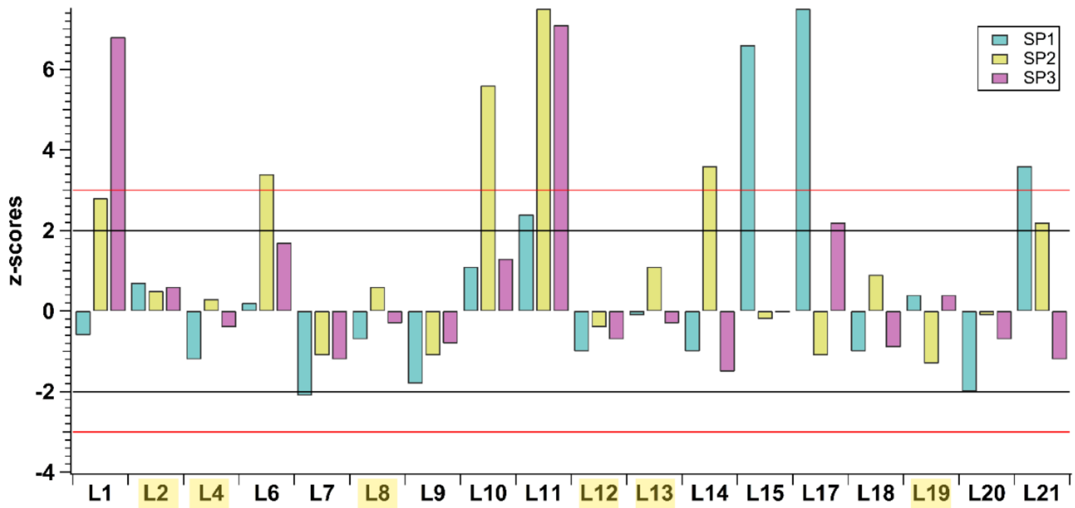

Figure 2: *Z-scores were calculated to evaluate each participant's performance in the interlaboratory comparison for each sample tested. Yellow-highlighted participants are the ones selected for the calculation of the assigned values. Black and red horizontal lines indicate boundaries for triggering an action signal a described in section 2.7.1. Dominutti et al., submitted.*

5. Demonstration analyses urban mapping

In this task, we first produced a protocol to map fine spatial-resolution air pollution concentrations based on (Mobile) monitoring (Deliverable D13 (D2.5)). This laid out the different approaches and their pros and cons for fine resolution urban mapping. Figure 3 provides the distinguished approaches.

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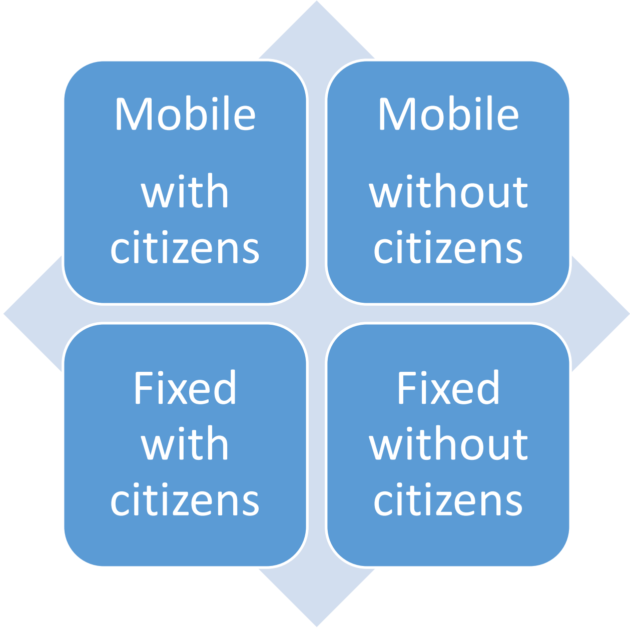

***Figure 3**: Schematic overview of different approaches for collecting data for high-resolution exposure mapping.*

We then applied these methods in pilot cities in Rotterdam, Birmingham and Bucharest. A variety of approaches was tested in these cities, following the scheme of figure 3. The results and experiences of these pilots were laid down in deliverable D14 (D2.6). Figures 4, 5 and 6 present maps in Rotterdam and Bucharest following specific approaches.

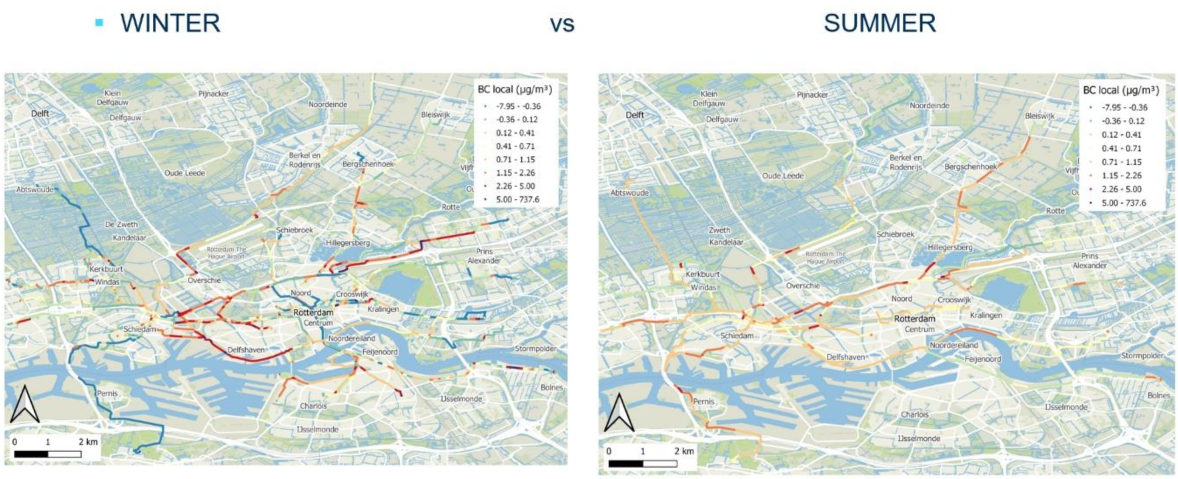

***Figure 4:** BC concentrations (µg/m^3) derived from mobile monitoring by bicycle in Rotterdam.*

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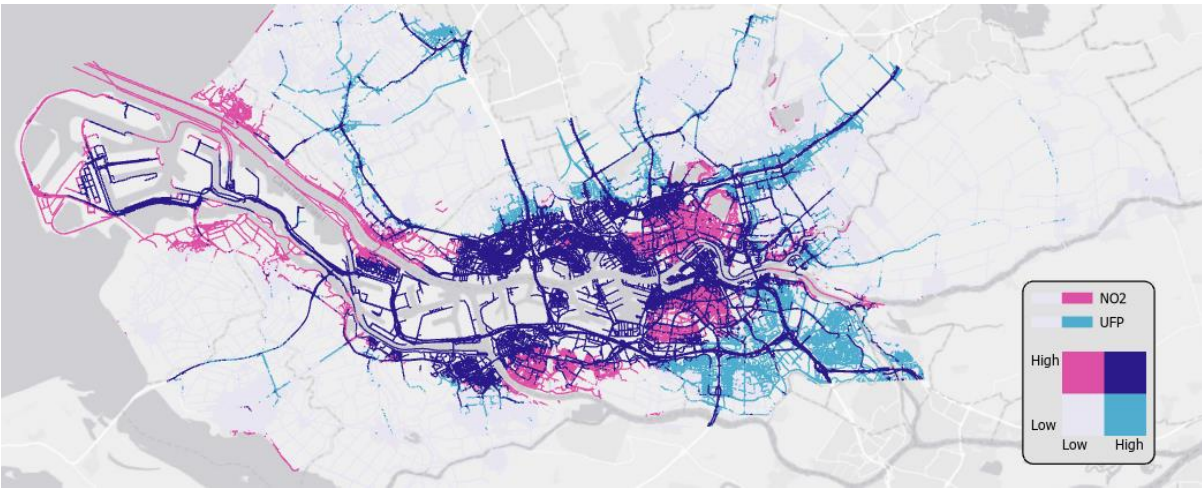

***Figure 5**: Ratio between predicted NO_2 and UFP concentrations in Rotterdam, resulting from car-based monitoring. Each of the four colors in the 2x2 box represent an equal number of road segments.*

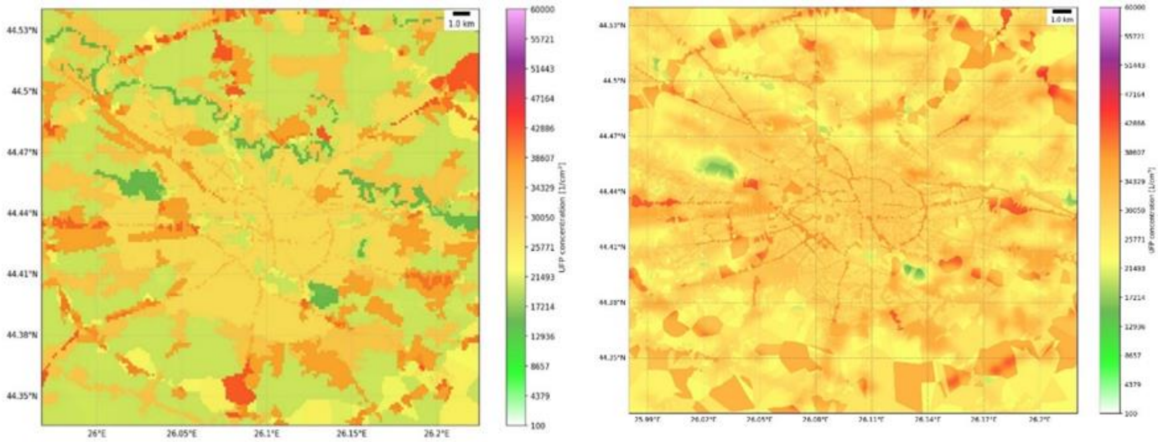

***Figure 6:** Model maps for UFP concentration levels in Bucharest during summer and winter period.*

Some overarching conclusions drawn in the evaluation of the pilot studies were:

- One overall message from the three pilot studies is that substantial new information can be learned by campaigns of mobile monitoring or low-cost sensor (LCS) fixed site indoor and outdoor monitoring of a limited duration (weeks to months) with a proper design. This makes these methods useful as an addition to routine monitoring with reference grade instruments at a small number of fixed sites. We note that these campaigns are intended to provide additional information to the fixed site monitoring, not replace such measurements, as they provide excellent temporal resolution (at a limited number of locations).
- Detailed frequent quality control is essential, both in studies employing low-cost sensors and in studies using reference grade instruments. Comparisons with routine monitoring stations prior to and after mobile monitoring studies are important. Results need to be evaluated immediately such that potential errors can be detected before embarking the campaign.
- In the three pilots, mobile campaigns were performed with cars, bicycles and pedestrians. All these options resulted in informative campaigns. It depends on the research question and the size of the study area which

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platform is most suitable. Cars lend themselves more easily to included non-portable reference grade instruments such as the AE33 aethalometer instead of the cheaper and portable AE51. With cars, also a larger study area can be covered, such as in the Rotterdam where measurements were conducted in the wider Rijnmond area. In general, the faster the platform, the higher temporal resolution and response time of the instruments are needed.

- As there is well-documented seasonal variability, and the aim is to create long-term average estimates, conducting monitoring in at least two seasons is crucial. If the interest is in specific sources e.g. wood burning than a season-specific campaign could be sufficient.
- In none of the pilots, it was feasible to perform mobile monitoring at night, hence the measured concentrations primarily reflect daytime averages. In the Rotterdam car pilot, a limited number of monitoring days were performed in the weekend, but as in the other pilots monitoring was mostly performed in weekdays. Night-time monitoring raises safety concerns when performed by cycling or walking.
- The approach of involving citizens in mobile monitoring of air pollution worked well, both in Birmingham and Rotterdam. Awareness raising, identification of hotspot locations, more representative personal exposure assessments in urban environments/during specific activities (e.g., commuting) were identified as added value of involving citizens in the Rotterdam pilot.
- The monitoring in itself was useful to document variability in space, e.g. between different homes in Birmingham using longer-term monitoring with LCS or along routes frequently driven by DCMR employees in Rotterdam. In addition, the monitoring served as data to derive empirical models, using machine-learning, and a manually guided stepwise linear regression, based on a variety of land use predictors.
- Mobile monitoring was an effective tool for characterizing spatial variation in the three pilot cities Rotterdam, Birmingham and Bucharest. Substantial variation was found within 1x1 km grid cells in all cities (Deliverable D27 (D4.6), WP4.3 and figures 14 and 15 included from the Bucharest pilot).

Based on the Deliverables D13 (D2.5) and D14 (D2.6), we produced a guidance document for urban mapping and citizen Science. Different approaches can be used to assess exposure to pollutant concentrations including ultrafine aerosol particles (UFP), black carbon (BC), nitrogen dioxide (NO_2), particulate mass below 2.5 µm ($PM_{2.5}$) at high spatial resolution for epidemiological studies and other applications. Mobile sensing platforms and fixed (low-cost) sensor networks can be used as complementary tools to data from fixed regulatory AQMN to map pollutant concentrations at a higher spatial density. These data are needed to obtain a better estimate of exposure and related health outcomes. We make a distinction between **mobile/fixed measurements** and experimental designs **with/without citizens**. The collected data can **be processed and analysed** using only measured data or using interpolation/modelling techniques like Land Use Regression (LUR)-based or machine learning models. The selected techniques used for data processing may have an impact on the required data collection approach. Each of the approaches has strengths and weaknesses. When selecting a method, the user needs to define the aim of the data collection and other considerations e.g. one may prefer to engage citizens as part of awareness training on AQ (Figure 4).

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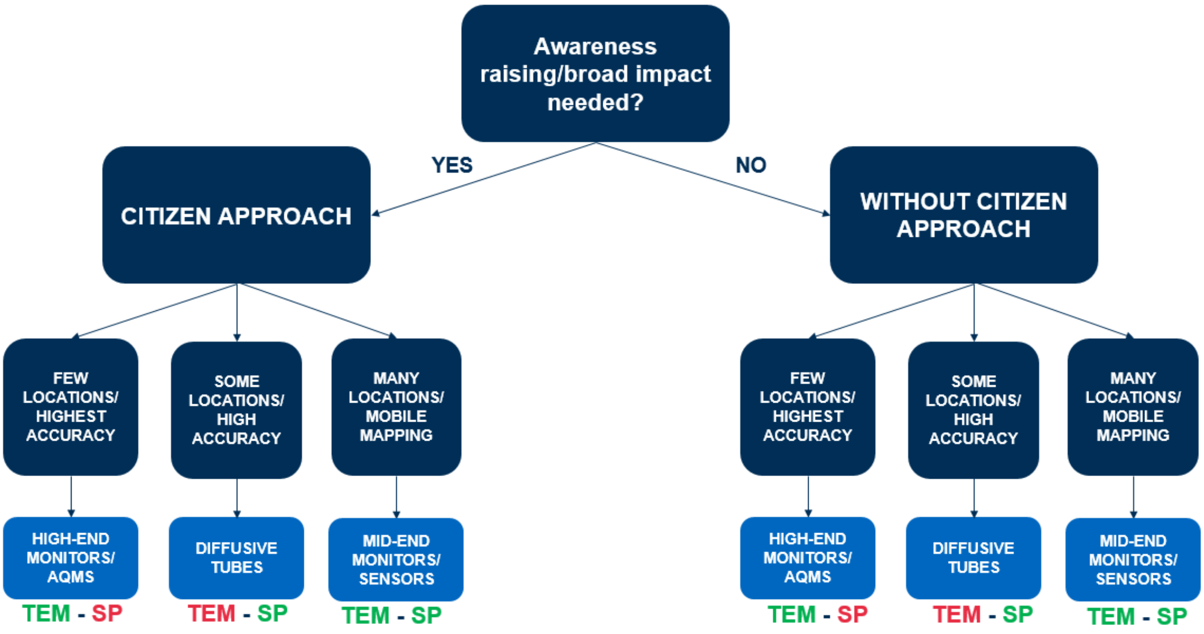

Figure 7: *Pathways for selecting methods for urban mapping. TEM refers temporal and SP to spatial. Green implies that the method performs well, red that is performs poorly for the spatial or temporal aspect.*

Mobile monitoring can be used to map pollutants at a high spatial resolution with a limited number of instruments (in contrast to stationary monitoring) and can also use high-end or mid-end instruments exhibiting higher data quality than sensors. Mobile monitoring has some challenges because of the spatiotemporal nature of the collected dataset. Care should be taken during data collection and/or data processing in order to obtain representative results.

Low-cost fixed sensor networks have several limitations, especially for the real-time sensors which have shown varying performances. Good performance has been documented for low-cost diffusive samplers. Diffusive samplers only provide weekly to monthly averages, but this may be sufficient for specific use cases. If so, diffusive samplers are the method of choice. While real-time sensors are able to provide very frequent measurements, they lack the accuracy of the substantially more expensive regulatory grade instruments and are greatly affected by extreme meteorological conditions (mainly high relative humidity). Therefore, a proper calibration and validation approach is needed. We recommend co-location performance evaluation to evaluate intra- and inter-sensor uncertainty and continuous calibration/validation under representative pollutant and meteorological conditions to compensate for seasonal effects from e.g. temperature and relative humidity. Regardless of that, they provide sensing opportunities that were not feasible before due to their portability and low cost. Using a spatially dense network can help in measuring and understanding the effect of sources that are usually “lost in the big picture”, such as the effect of hyper-local sources of pollution.

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