Deliverable D40 (D5.6)

Replicating AQ monitoring solutions: Warsaw and applicability to other cities

RI-URBANS

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

By

UW

31/01/2025

RI-URBANS (www.RIURBANS.eu) is supported by the European Commission under the Horizon 2020 – Research and Innovation Framework Programme, H2020-GD-2020, Grant Agreement number: 101036245

Deliverable D40 (D5.6): Roadmap: Replicating AQ monitoring solutions: Warsaw and applicability to other cities

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Work package (WP)	WP5 / Health effect assessment of PM, PM components, nanoparticles, and their source contributions
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Version	Final
Reviewed by	WP5 leaders and project coordinators
Accepted by	RI-URBANS Project Coordination Team
Comments	This report summarises the proposal for upscaling the RI-URBANS supersite measurements in four cities of Poland, including Warsaw. Initially it was planned for Warsaw but with the request of the new European AQ Directive for implementing supersites, it was extended to four cities. We organized meetings with stakeholders to present the roadmap to implement measurements in sites with available instrumentation or to purchase in case of absence. Ctizens and mechanisms to enroll citizens that can be readily upscaled at European level.

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Table of Contents

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1. ABOUT THIS DOCUMENT

This document summarises the proposal for upscaling urban air quality (AQ) supersites in Poland to fulfil the requirements of the proposal for a new EU AQ Directive (NAQD) based on guidance of RI-URBANS/ACTRIS.

RI-URBANS is a European Commission (EC) Horizon-2020 funded project (grant agreement 101036245) to demonstrate how Service Tools (STs) from atmospheric Research Infrastructures (RIs) can be adapted and enhanced to provide advanced AQ measurements in European cities and industrial, harbour, airport and road traffic hotspots, as well as in areas with significant levels of air pollution and associated health effects. RI-URBANS combines advanced scientific knowledge and innovative technical work to develop pilot STs that will enhance the capacity of the Air Quality Monitoring Networks (AQMNs) to provide the necessary observations to evaluate, predict and abate urban air pollution. RI-URBANS focuses on human exposure to outdoor ambient ultrafine particles (particle number concentration finer than 100 nm.; UFP), particle number size distribution (PNSD), black carbon (BC), particulate matter (PM) speciation, oxidative potential (OP), ammonia (NH_3). Furthermore, a list of 48 volatile organic compounds (VOCs) for measurements is also included in Annex VII of the proposal.

The project is directly connected with **ACTRIS** (Aerosol, Clouds and Trace Gases Research Infrastructure) and **ICOS** (Integrated Carbon Observation System) in terms of use of STs, networking supersites and data management. Since more than a decade, the Pan-European ACTRIS initiative, has actively developed the advanced high-quality observing system for short-lived atmospheric constituents relevant to climate and AQ studies.

This is a public document, available at the RI-URBANS website, https://riurbans.eu/work-package-5/, and distributed to all RI-URBANS partners for their use as well as submitted to the European.

This is a public document that will be distributed to all RI-URBANS partners for their use and submitted to European Commission as a RI-URBANS deliverable D40 (D5.6). This document can be downloaded at https://riurbans.eu/work-package-5/#deliverables-wp5.

2. SCOPE

On 26/10/2022 DG ENV from the EC issued a proposal for a new AQD, and on the 08/03/2024 a final proposal was agreed between the Council of Europe and the European Parliament, which was submitted for approval to the two institutions. This proposal for a NAQD in Europe requires in Art10 to build up a network of supersites for measuring advanced AQ parameters, such as UFP, PNSD, BC, PM speciation, OP, and NH_3. Furthermore, a list of VOCs to be measured is included also in Annex VII. The new AQ directive was published on 20th November 2024 and currently EU countries undergo the legalization and implementation process.

On the other hand, the EU launched the Mission of Climate Neutral and Smart Cities. There are currently 112 climate-neutral smart cities that are willing to be labelled as a such before 2030. Among other, several cities in Poland, i.e. Kraków , Łódź, Rzeszow, Warsaw, and Wrocław are included in this list of cities. As 31st December 2024, 43 cities have received the label are: Leuven (Belgium), Limassol (Cyprus), Espoo, Lahti, Lappeenranta, Tampere, Turku (Finland), Marseille, Lyon (France), Aachen, Heidelberg, Münster (Germany), Ioannina, Kalamata, Kozani, Thessaloniki, Trikala (Greece), Miskolc, Pecs (Hungary), Eilat (Israel), Bologna, Bergamo, Florence, Milan,Parma,

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Prato, Turin (Italy), Liepāja (Latvia), Guimaraes, Lisbon, Porto (Portugal), Bucharest 2nd District, Suceava (Romania), Barcelona, Seville (Spain), Ljubljana, Kranj (Slovenia), Gothenburg, Gävle, Malmö, Umeå (Sweden), The Hague (the Netherlands), and Izmir (Türkiye).

There are continuous calls to which the Polish cities might apply, and once they receiving the label they have exclusive funding opportunities to implement their actions.

It is also very relevant that measurements with climate and air quality focus should be also collocated as advised the EC in many information events from DG ENV.

The work package (WP) 5 of RI-URBANS aims to provide guidance for upscaling the STs provided by WP1-4. Specifically, task 5.4 in WP5 focuses on providing guidance for upscaling them in Poland. This report provides the output of this task, which included an initial stakeholder meeting in Poland, followed by interaction with research teams from the country to elaborate this guidance document.

This document will be presented and delivered to the AQ competent administration from Poland with recommendations drafted in RI-URBANS to support current measurements and complement additional ones to upscale the STs.

3. THE FIRST STAKEHOLDERS IN POLAND

The RI-URBANS Polish Stakeholder Meeting took place in hybrid format at the Institute of Geophysics, Faculty of Physics, University of Warsaw on 23rd February 2023. The Polish stakeholders representing 23 institutions attended the meeting, including 16 institutions with representatives in person (20 persons) and 9 institutions online (11 persons). In addition to Polish stakeholders, in this meeting also 6 representatives of the RI-URBANS and the ATMO-ACCESS projects participated (online).

The meeting was organised by the staff of the Institute of Geophysics of the Faculty of Physics at University of Warsaw. The Organizing Committee was composed of following members: Iwona Stachlewska (lead organiser), Katarzyna Dyl (meeting secretary), Lucja Janicka and Dominika Szczepanik (merit support), Dabrówka Stępniewska (logistics), Wojciech Kumala (technical support).

The objective of this meeting was to show the RI-URBANS/ACTRIS STs for measuring advanced AQ parameters developed, the added value and the relationship with the requirements of the NAQD for urban areas.

3.1 Attendees

Below is the list of the institutions which representatives took part in the meeting.

20 participants of 16 Polish institutions attended the meeting onsite (i.e., face-to-face attendees) from:

i. Ministerstwo Edukacji i Nauki, Departament Innowacji i Rozwoju (MEiN)
ii. Główny Inspektorat Ochrony Środowiska, Departament Monitoringu Środowiska (GIOŚ / English: CIEP)
iii. Główny Inspektorat Ochrony Środowiska, Krajowe Laboratorium Referencyjne do spraw jakości powietrza (GIOŚ-KLR)
iv. Instytut Ochrony Środowiska - PIB, Stacja Kompleksowego Monitoringu Środowiska "Puszcza Borecka" (IOŚ-SKMŚ / English: IEP-NRI)
v. Urząd Miasta Stołecznego Warszawy, Biuro Ochrony Powietrza i Polityki Klimatycznej (U.M.St. Warszawa BOPPK)

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vi. Urząd Miasta Stołecznego Warszawy, Biuro Strategii i Analiz (U.M.St. Warszawa BSA)
vii. Europejskie Centrum Czystego Powietrza (ECAC)
viii. Sejmik Śląski, Urząd Marszałkowski Województwa Śląskiego
ix. Uniwersytet Warszawski, Centrum Współpracy i Dialogu (UW CWD)
x. Akademia Górniczo-Hutnicza im. Stanisława Staszica w Kraków ie, Wydział Fizyki i Informatyki Stosowanej (AGH)
xi. (ACTRIS-Poland Konsorcjum Lider) Instytut Geofizyki Polskiej Akademii Nauk, Zakład Fizyki Atmosfery (IGFPAN)
xii. (ACTRIS-Poland) Instytut Podstaw Inżynierii Środowiska Polskiej Akademii Nauk (IPIŚ-PAN)
xiii. (ACTRIS-Poland) Uniwersytet Warszawski, Wydział Fizyki, Instytut Geofizyki (UW WF)
xiv. (ACTRIS-Poland) Politechnika Warszawska, Wydział Instalacji Budowlanych, Hydrotechniki i Inżynierii Środowiska (PW)
xv. (ACTRIS-Poland) Uniwersytet Śląski w Katowicach, Wydział Nauk Przyrodniczych (UŚ)
xvi. (ACTRIS-Poland) Uniwersytet Wrocławski, Instytut Geografii i Rozwoju Regionalnego (UWR)

11 participants of 9 Polish institutions attended the meeting online from:

i. Urząd Miasta Stołecznego Warszawy, Biuro Ochrony Powietrza i Polityki Klimatycznej (U.M.St. Warszawa BOPPK)
ii. Urząd Miasta Lublin, Wydział Strategii i Przedsiębiorczości (UM Lublin)
iii. Urząd Miasta Bydgoszczy, Referat Ochrony Powietrza (UM Bydgoszcz)
iv. Polska Agencja Kosmiczna, Departament Obserwacji Ziemi (POLSA)
v. Instytut Ochrony Środowiska, Zakład Zintegrowanego Monitoringu Środowiska (IOŚ - ZZMŚ)
vi. Instytut Rozwoju Terytorialnego (IRT)
vii. Uniwersytet Wrocławski, Instytut Geografii i Rozwoju Regionalnego, Grupa Modelowania (UWR)
viii. (ACTRIS-Poland) Uniwersytet Przyrodniczy w Poznaniu, Wydział Inżynierii Środowiska i Inżynierii Mechanicznej (PULS)
ix. (ACTRIS-Poland) Instytut Meteorologii i Gospodarki Wodnej - Państwowy Instytut Badawczy (IMGW-PIB)

In this meeting 6 representatives of the RI-URBANS and the ATMO-ACCESS were present (online).

RI-URBANS:

i. Xavier Querol Carceller and Marta Monge Azemar, Spanish National Research Council (CSIC), Institute of Environmental Assessment and Water Research,

ii. Tuukka Petäjä, University of Helsinki, Institute for Atmospheric and Earth System Research (INAR).

iii. Eleni Athanasopoulou and Kyriakos Romios, National - National Observatory of Athens, Institute for Environmental Research & Sustainable Development

ATMO_ACCESS:

i. Ariane Dubost, CNRS-LAMP Université Clermont Auvergne (UCA).

3.2. Summary of the meeting

The meeting started at 9:15 am local time with the welcoming speech by Iwona Stachlewska, the co-leader of Task 5.4 in WP5 of RI-URBANS. She explained to the audience what the main goals of the meeting are and expressed the need for collaborative and complementary work between the key players in relation to these goals in a consolidated way. Directly afterwards, Xavier Querol, the coordinator of RI-URBANS, presented online the main objectives of the project, including the key goal being linked to the health issues, to be researched within work in the core pillars of

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near-real-time (NRT)-Monitoring, Mapping, and Modelling, as serving for demonstration and upscaling exercises in different locations in Europe. Important part of his talk addressed the context of the revision of the NAQD. Tuukka Petäjä, the co-coordinator of the RI-URBANS, added comments in relation of linking between the RI-URBANS RIs and other infrastructures e.g. ACTRIS. Michał Rybiński, Head of the Department of Innovation and Development at the Ministry of Education and Science (MEiN) of Poland commented on the initiative from the point of view of the geographical representativeness of RI-URBANS in the context of lacking sites in Central-Eastern Europe. Xavier Querol explained in more detail the concept of supersites and context of monitoring to provide relevant input for health and mortality assessments due to low AQ in urban areas. After the questions for the presentation, at 10 am, the merit discussion (in Polish) started. The majority of the representatives of Polish stakeholders have spoken and expressed their positions or their institutions. In general, the most important voice to be heard was this from the perspective of the Polish Chief Inspectorate of the Environmental Protection (CIEP). Barbara Toczko, Deputy Director of the Environmental Monitoring Department at CIEP, explained the specificity of the monitoring programme and operational differences from the observational networks run within research-based activities. Barbara also explained the legal work frame of the CIEP monitoring and its relations to activities of the Institute of Environmental Protection – National Research Institute (IEP-NRI). Krzysztof Skotak, Manager of the Comprehensive Environmental Monitoring Station at IEP-NRI highlighted the need of the high-quality, standardised data provision form monitoring purposes and as for input to modelling of AQ.

Several representatives raised an important topic of the current direct financing of the obligatory monitoring activities and the likely need of co-financing if the monitoring should be extended to new variables. There were also important voices expressing the need for a good definition of the common goal and purpose of the state monitoring and the observational research infrastructure collaboration.

There were voices expressing that there is obviously an interest in the data collected and reported to the EU by CIEP but the usage of the data could be increased, especially by the scientific community. Łukasz Adamkiewicz, President of the European Clean Air Centre (ECAC), raised a crucial point on low visibility of the ACTRIS at the Polish national level. Wojciech Cyran, representing the Polish Space Agency, revealed the need to use satellite data in the AQ monitoring. An insight on, respectively, the atmospheric (high-tower) sites and the ecosystem sites planned to be included within ICOS development in Poland, was given by Jakub Bartyzel representing the AGH Universty of Kraków (AGH), and Bogdan Chojnicki representing the Poznan University of Life Sciences (PULS). As there were also several comments of lack of knowledge of the access to data collected within the existing RIs. Thus, Iwona Stachlewska asked the participants to listen to the next talk that was partly addressing this topic.

At 11 am an online presentation by Eleni Athanasopoulou, the organiser of the ATMO-ACCESS Trans-National-Access (TNA) activities for public authorities and member of RI-Urbans WP 5 (NOA), was delivered. The aim of this talk was to show the possibilities offered with a particular emphasis on the new public authorities call that can be co-designed with them. The focus was on specific examples of the different types of the possible access to the ACTRIS and ICOS facilities all over Europe offered within the TNA of ACTRIS. After the talk, the discussion (in Polish) followed on both the main access pathways to the data, facilities, instrumentation, calibration services, and joint-research opportunities within TNA and non-TNA collaboration. It seems there was an interest in the co-designed call. This will need to be further elaborated.

Iwona Stachlewska, taking her role as the ACTRIS-Poland Implementation Coordinator, apologised for not planning to show any presentation related to ACTRIS development in the country, which she saw of an importance only during the meeting. Thus, at 12:30 am she presented a concise, not-scheduled talk on the ACTRIS implementation, focusing on explanation of the main ACTRIS long-term goals, access pathways, financing, QA&QC procedures, geographical locations of the existing sites, etc. In this contest, she invited the participants to have a tour in the ACTRIS research facility in Warsaw available for TNA within the ATMO-ACCESS (Warsaw Observatory Station -

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WOS). Those tours were done in groups before and after lunch led by Dominika Szczepanik and Lucja Janicka from UW.

In parallel, there was a vivid continuation of the previous discussion in the general forum, having a focus back on the RI-URBANS related activities at the national level. Specifically, Magdalena Reizer, representing the Warsaw University of Technology (PW) and Krzysztof Klejnowski, representing the Institute of Environmental Engineering of the Polish Academy of Science (IPIŚ-PAN) declared their willingness to support the preparation of the upscaling strategy for the Warsaw showcase in relation to the merit and technical aspects of such exercise to be completed for RI-URBANS. This strategy obviously will have to be supported with the standard observations of CIEP and IEPNRI. Mariola Jabłonska, Director of the University Laboratories for Atmosphere Control at the University of Silesia (UŚ - ULKA) offered to provide her input in the context of the measurements with the instrumented mobile and airborne platforms.

From a more general point of view, the majority of the participants expressed high interest in discussing among their institutions the aspects of the proposed changes in the revision of the NAQD. They were very interested to obtain the document describing the RI-URBANS/ACTRIS response, comments and recommendations on the current, publicly available, directive revision proposal. Several participants expressed that a solid and community-agreed response from Poland would be very beneficial in this case. The meeting was concluded with an expression of need to continue the established collaboration during follow up joint-meetings to be conducted on a regular basis. This would give a chance to the stakeholders to acquaint themselves even better with the RI-URBANS and ATMO-ACCESS initiatives, which in long-term may result in a more direct collaboration between them. Iwona Jelonek, in her role of representative of the Marshal Office of the Silesian Voivodeship, expressed gratitude to be invited to attend the meeting and thanked all presenters and the participation stakeholders for performing such important work that can impact the decision-making process at the different levels. Iwona Stachlewka ended the meeting at 15:00 pm by thanking all participants to take their time to attend the meeting, listen to the talks, share openly their views, express their needs and provide in overall an optimistic view towards the future collaboration.

On 28 February 2023, the material from the meeting (flyer, e-mail list, all meeting presentations) was distributed via e-mail to all meeting participants. The meeting was successfully conducted. The contacts between different Polish stakeholders were strengthened, and a link was established with RI-URBANS. The understanding of the RIs has been improved at national level. All relevant information has been disseminated to the meeting participants.

Subsequent and frequent interactions between RI-URBANS/ACTRIS scientists and universities from Poland yielded to recommendations for upscaling the STs required in the NAQD that are presented in subsequent sections.

4. SUGGESTIONS FROM RI-URBANS FOR UPSCALING STs

After the meeting, interactions between RI-URBANS and five Polish research/academic teams specializing in urban measurements took place. These interactions led to the development of **guidance for upscaling four urban sites in Poland** to support the requirements for urban supersite measurements of the NAQD.

The Warsaw Supersite (WAW) operated by the University of Warsaw, Faculty of Physics was a single site initially proposed for upscaling in Poland, as a partner within RI-URBAN project and ACTRIS National Facility (*in labelling process***). This supersite is supported also by the Warsaw University of Technology.** It represents the capital and largest Polish city with very specific flat-orography, spacious but highly urbanized environment in relatively low emission source province of Mazovia. **The other three proposed supersites (WRC in Wrocław operated by the University of Wrocław, GZM in Zabrze operated by the Institute of Environmental Engineering of the Polish Academy of Sciences, and KRK in Kraków operated by the AGH University of Kraków)** represent specific Polish

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urban environments, each with a different location, emission sources (provinces of Lower Silesia, Silesia, Lesser Poland), and range of urban air quality issues.

The measurements required for urban supersites in the proposal for a NAQD are listed in Annex VII as follows:

Pollutant	***Type of measurements***
PM_{10}, $PM_{2.5}$, UFP, BC	Fixed measurements
NO_2, O_3	Fixed measurements
SO_2, CO	Fixed or indicative measurements
Size distribution of UFP	Fixed or indicative measurements
Benzo(a)pyrene, other polycyclic aromatic hydrocarbons (PAH) as relevant	Fixed or indicative measurements
Total deposition of benzo(a)pyrene, and other polycyclic aromatic hydrocarbons (PAH) as relevant	Fixed or indicative measurements
Arsenic, cadmium, lead, and nickel	Fixed or indicative measurements
Total deposition of arsenic, cadmium, lead, nickel and mercury	Fixed or indicative measurements
Benzene	Fixed or indicative measurements
Chemical composition of $PM_{2.5}$ in accordance with Section 1 of Annex VII	Fixed or indicative measurements

Measurement of $PM_{2,5}$ must include at least the total mass concentration and concentrations of appropariate compounds to characterise its chemical composition. At least the list of chemical species given below shall be included.

SO_4^{2-}	Na^+	NH_4^-	Ca^{2+}	elemental carbon (EC)
NO_3^-	K^+	Cl^-	Mg^{2+}	organic carbon (OC)

Furthermore, the NAQD recommends (no requests) implementing measurements of NH3 and levoglucosan, and oxidative potential of PM.

4.1. Statement on potential of ACTRIS-Poland to meet requirements of Air Quality Directive

For reference and information, we provide “Statement on the potential of ACTRIS-Poland to meet the requirements of the Air Quality Directive” communicated on 11 December 20204 to the Polish Chief Inspectorate of the Environmental Protection (CIEP):

Research infrastructure consortium ACTRIS-Poland is the country contribution to the European Research Infrastructure ACTRIS-ERIC. In accordance with the decision no. DIR/PMIB/2020/131, the Minister of Science and Higher Education (MNiSW) entered ACTRIS Poland on the Polish Research Infrastructure Map.

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ACTRIS-Poland is developing the following stations that conduct or will conduct aerosol measurements using in-situ techniques:

- Wrocław, ul. Kosiby 8 (University of Wrocław, UWR) - city station,
- Racibórz, ul. Chłopska 1 (IGF PAS) - urban-industrial station,
- Besk Duży, ul. Osiedle PAN 1 (IGF PAS) - regional background station.
- Warsaw, ul. Pasteura 5 (UW/WUT) – planned expansion of existing observational platform – city station

The following measurements are curently carried out at Wrocław and Racibórz stations (according to the ACTRIS nomenclature):

- Particle number size distribution – mobility diameter from 10 to 800 nm
- Particle number concentration on DP50= 10 nm
- Particle number size distribution - aerodynamic diameter 0.8 to 10 µm,
- Particle light absorption coefficient and/or equivalent black carbon concentration
- Particle light scattering & backscattering coefficient – multiwavelength
- gravimetric measurements of suspended particulate matter (PM) using a low-flow automatic aerosol collector.

Chemical analysis of aerosol composition in terms of ion content, heavy metals, OC EC, biomass combustion markers, and oxidation potential will be performed by the ACTRIS-Poland supporting laboratory of IEE PAS in Zabrze.

The stations in Wrocław and Racibórz have started the "ACTRIS labeling" process in the scope of aerosol in situ measurements. The operating costs of the above-mentioned stations for 2024-2028 are secured with the MNiSW funding program "*Support for the participation of Polish scientific teams in international research infrastructure projects*".

As part of the *Update of the Polish Research Infrastructure Map* announced on November 14, 2024 by MNiSW, the ACTRIS-Poland consortium officially announced its intention to expand the station in Warsaw with an in-situ component. The equipment and measurement range of this station will be similar to Wrocław/Racibórz, and the entity responsible for the development and operation of the station will be the Warsaw University of Technology (WUT), in cooperation with the University of Warsaw (UW). The proposed location of the station is a measurement container located at the corner of Pasteura and Banacha Streets in Warsaw.

With regard to the implementation of the provisions of DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL (EU) 2024/2881 of 23 October 2024 on ambient air quality and cleaner air for Europe, the following measurements conducted at ACTRIS stations may be used within the scope of the obligation to conduct measurements on the so-called "super stations":

- Quantitative concentration of particles above 10 nm, corresponds to the concentration of "ultrafine particles" / "UFP" in Directive 2024/2881
- Quantitative size distribution of aerosols in the range of 10 - 800 nm, corresponds to the parameter "ultrafine particle size distribution", "UFP size distribution" ” in Directive 2024/2881
- Concentration of soot and organic carbon in the aerosol, light absorption coefficient, corresponds to the measurements of "soot" or "BC" ” in Directive 2024/2881
- collection of aerosol samples on filters using the gravimetric (reference) method, followed by analysis of the carbon content and NO3-, SO42-, Cl-, NH4+, Na+, K+, Mg2+, Ca2+ ions in PM2.5 in the air

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All measurements are/will be performed in accordance to ACTRIS Standard Procedures for In-Situ Aerosol Sampling, Measurements, and Analyses at ACTRIS Observatories, ACTRIS-ERIC Version 1.0; January, 2024) or the methodology proposed in the RI-URBANS project, i.e.:

- Sample collection and drying is performed, among others, in accordance with GAW Report No. 227,
- Measurement of the quantitative concentration of particles above 10 nm is carried out in accordance with the EN-16976 standard,
- Measurement of the quantitative size distribution of aerosols in the range of 10 - 800 nm is carried out in accordance with the CEN/TS-17434 specification
- Aerosol sampling on filters is carried out in accordance with the EN 12341:2023 standard, ion analysis is performed in accordance with the same standard, while the determination of the content of elemental and organic carbon (OC/BC) is carried out in accordance with the EN 16909:2017 standard.

Due to the lack of normative documents on determining the oxidation potential, measurements in this area will be carried out in accordance with the guidelines of the RI-URBANS document (Research Infrastructures Services Reinforcing Air Quality Monitoring Capacities in European Urban & Industrial AreaS (GA n. 101036245); GUIDANCE DOCUMENTS ON MEASUREMENTS & MODELLING OF NOVEL AIR QUALITY POLLUTANTS: Oxidative Potential of Particulate Matter). It is planned to conduct research on determining the oxidation potential using dithiothreitol (DTT), ascorbic acid (OPAA), glutathione (OPGSH), uric acid (OPUA) and 2,7-dichlorodihydrofluorescein (OPDCFH). The IEE PAS Research Laboratory plans to begin work in 2025 on developing and validating a methodology for determining the oxidation potential of particulate matter collected on filters.

The ACTRIS-Poland consortium members declare full availability of the above measurement data, as well as full substantive support in implementing and carrying out measurements resulting from Directive 2024/2881 in the scope of conducting non-standard measurements at "super stations".

This statement was consolidated by ACTRIS-Poland Consortiants: Aleksander Pietruczuk (IGF PAS), Anetta Drzeniecka-Ociadacz (UWR), Magdalena Reizer (WUT) and Iwona Stachlewska (UW).

4.2. Urban supersites, research teams and contact points

Herewith, taking into account the ACTRIS-Poland statements as well as the reccomendations for the choice of the urban sites according to the Directive 2024/2881 we are proposing four supersites. Depicted in Figure 1 we show the locations of the four cities of Warsaw, Wrocław, Zabrze and Kraków in Poland, where the four proposed urban/suburban supersites are located.

The remining two sites (Figure 1 in blue) are Raciborz and Belsk sites both not considered in this document as potential for urban supersite. Raciborz site was not considered due to its too small size in terms of polulation (50 743 citicens) and surface (75m^2); sensus on 31/12/2021. Belsk site was not considered due to its characteristics, although it is declared as urban/industrial site, it is located in the direct vicinity of the Modrzewina Nature Reserve. However, their lates choise as supersites cannot be considered as entirely excluded.

The final decision on the locations of the supersites lies in gestion of the he Polish Chief Inspectorate of the Environmental Protection (CIEP) and final commitment of the interested Research performing organization.

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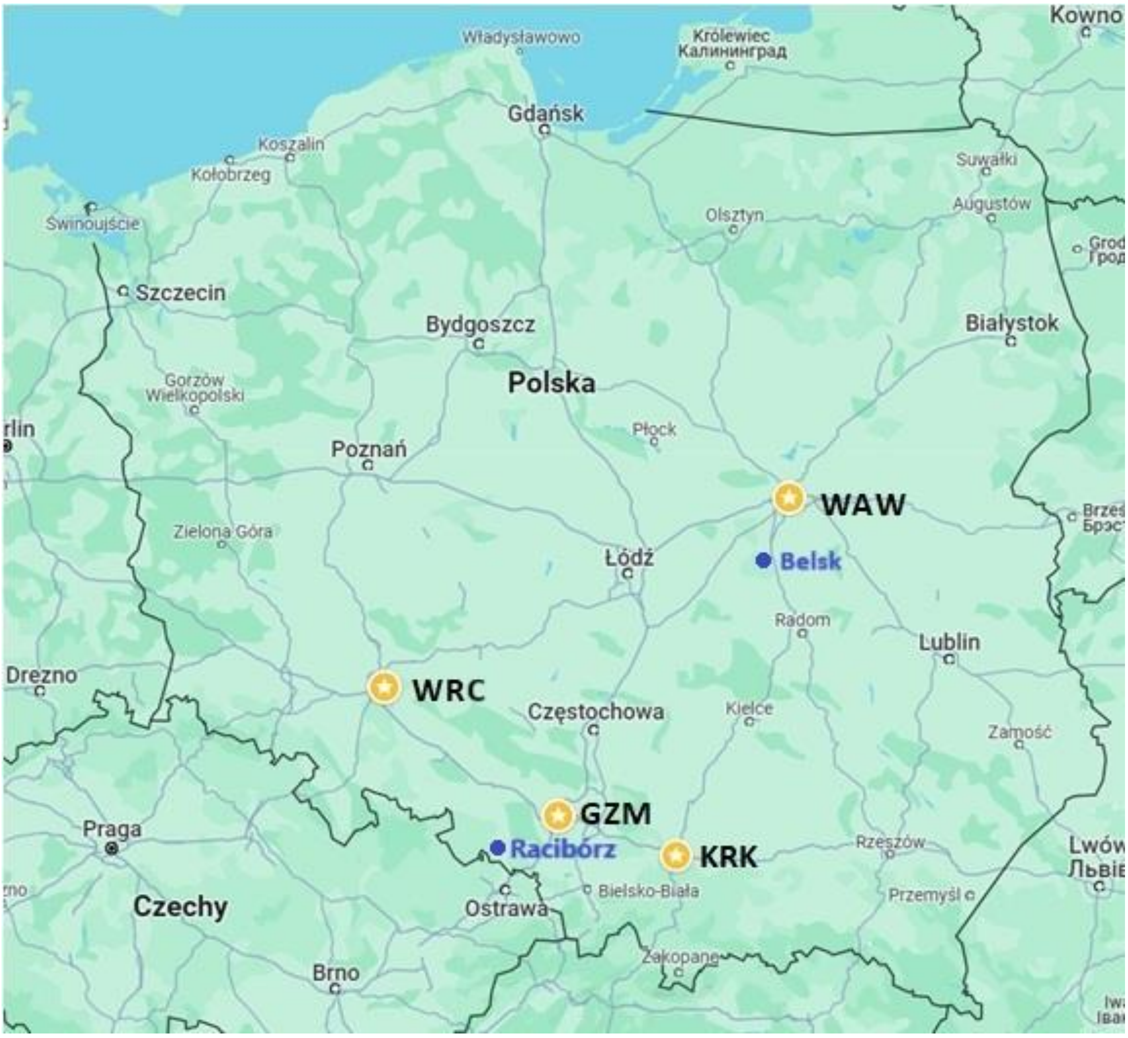

Figure 1. *Location of Warsaw (WAW), Wrocław (WRC), Górnośląsko-Zagłebiowska Matropolia (GZM), Kraków (KRK) in Poland, where the four proposed urban/suburban supersites are located. Remining ACTRIS-Poland in-situ sites are indicated in blue.*

The Polish research/academic teams working in atmospheric measurements in the four proposed supersites, and the respective leaders, are:

- Warsaw (WAW): **University of Warsaw, Faculty of Physics, Institute of Geophysics**; PI: Prof. Iwona Stachlewska, RI-URBANS partner, PI of Warsaw ACTRIS/PolandAOD site, Co-Chair of ACTRIS National Facility Technical & Scientific Forum. She is leading a supersite in urban Warsaw devoted to height-derived and columnar measurements of atmospheric parameters, aerosols, clouds, and radiation.
- Warsaw supersite activities are officially planned to be complemented with observations collected and conducted by **Warsaw University of Technology** (PI: Dr Magdalena Reizer), especially in terms of AQ related observations.
- Wrocław (WRC): **University of Wrocław, Institute of Geography and Regional Development, Department of Climatology and Atmosphere Protection**; PI: Dr Anetta Drzeniecka-Osiadacz, PI of Wrocław ACTRIS/PolandAOD site. She is leading a supersite in urban Wrocław devoted to both surface and column measurements of atmospheric parameters and aerosols.
- Górnośląsko-Zagłebiowska Matropolia (GZM): **Institute of Environmental Protection, Polish Academy of Sciences**; PI: Dr Barbara Błaszczak. She is leading a supersite in the metropolis devoted to surface measurements of atmospheric parameters, aerosols and gases.

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- Kraków (KRK): **AGH University of Kraków**; PI: Prof. Mirosław Zimnoch. He is a lider of AGH Kraków research station devoted to surface observations of AQ parameters and radiation.

WAW is a well-equipped ACTRIS National Facility and national measuring network PolandAOD site with focus mostly on columnar and height-derived measurements within the troposphere; while some surface measurements are also available. The site generally requires support for implementation of several surface AQ measurements of the RI-URBANS/ACTRIS urban supersites, coinciding with those requested by the NAQD draft. The WAW site run by University of Warsaw is currently under formalization of collaboration with Warsaw University of Technology for further extending the range of observations to AQ measurements.

WRC is a well-equipped ACTRIS National Facility and PolandAOD site that recently implemented a number of surface AQ measurements following the RI-URBANS/ACTRIS protocols, which with relatively low support would fulfil the requests of the NAQD and RI-URBANS/ACTRIS recommendations for urban supersites.

GZM is a site that currently has a supporting role to all ACTRIS National Facilities in Poland being a consociate of ACTRIS-Poland. It is very well equipped with in-situ instrumentation that suit very well the surface AQ purpose.

KRK is an urban location where specific air quality problems typical of foothill areas are observed as a result of large meteorological and topographic variability. The site is not in ACTRIS-Poland Consortia. It is sufficiently equipped with in-situ instrumentation that partly suit the surface AQ purpose.

4.2.1. WAW: Warsaw - the supersite at University of Warsaw

Institution: University of Warsaw, Faculty of Physics, Institute of Geophysics,
Site name: WAW / ACTRIS
Contact: Iwona Stachlewska (Iwona.Stachlewska@fuw.edu.pl).
Location: Warsaw, ul. Pasteura 5 (52° 12’ 39’’ N, 20° 58’ 58’’ E, 112 m a.s.l.)

Institution: Warsaw University of Technology / Institute of Environmental Engineering - Polish Academy of Sciences
Site name: WUT / IEE PAS
Contact: Magdalena Reizer (magdalena.reizer@pw.edu.pl).
Location: Warsaw, ul. Koszykowa 81 (52° 13’ 18’’ N, 20° 59’ 33’’ E, 113 m a.s.l.)

Geographically, Warsaw, the Capital City of Poland, is the country largest city, with population estimated at 2 million residents (in city) and within entire metropolitan area of 3.3 million residents, which makes Warsaw the 7th most-populous city in the European Union. The city area measures 517 km^2 and comprises 18 districts. The metropolitan area covers 6,100 km^2. Warsaw is an alpha global city, a major cultural, political and economic hub, and the country's seat of government. It is also capital of the Masovian Voivodeship.

Warsaw is located in east-central Poland, approximately 300 km from the Carpathian Mountains and 260 km from the Baltic Sea. Agglomeration lies within the heart of the vast Masovian Plain (also known as the Mazovian Lowland) that contributes to the city’s overall landscape. Warsaw boasts a diverse land cover with two main geographical features: flat land and plains - making it an ideal location for urban development and infrastructure, and occasional hills adding some variation to its topography. Green space covers almost a quarter of Warsaw's total area; from small neighbourhood parks, green spaces along streets and in courtyards, to tree-lined avenues, large historic parks, nature conservation areas and urban forests at the fringe of the city. There are 82 parks in the city; the oldest and largest are the Saxon and Krasiński Gardens, Łazienki Park (Royal Baths Park) and Wilanów Palace Parkland.

Warsaw is a considerable transport hub linking Western, Central and Eastern Europe. The city has a good network of buses and expanding perpendicular metro running north to south and east to west. The tram system is one of

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the biggest in Europe, with a total length of 133 km. The city undertakes construction of new roads, flyovers and bridges, current statistics for transport coverage are: Metro 41km, Trams 133 km, Buses 3000 km, Fast Urban Railway 116 km, WKD Commuter Railway 33km, and Koleje Mazowieckie (regional carrier operating within the city limits). Warsaw lacks a complete ring road system and most traffic goes directly through the city centre, leading to the eleventh highest level of congestion in Europe. The city has two international airports: Warsaw Chopin Airport, located just 10 kilometres from the city centre, and Warsaw-Modlin Airport, located 35 kilometres to the north. Warsaw lies on the Vistula River, being one of the core pollution ventilation channels.

Warsaw's climate, as classified by the Köppen-Geiger system, falls under the continental wet (Dfb) category, characterized by cold winters and brief warm summers. The annual temperature spectrum ranges from - 1.8 °C in January to 19.2 °C in July, with an average annual rainfall of 529 mm and relative humidity averaging at 79% (Weather-Atlas, 2020). In general, the heat-island effect contributes to the overall weather conditions of Warsaw agglomeration.

So far this proposed urban supersite consisted with two sites in the above close locations inside Warsaw (refer to Figure 2a), which complement each other as far as measurements that they carry out (see Table 1). In the future co-location of both sites will be done by moving permanently WUT/IEE instrumentation to WAW location.

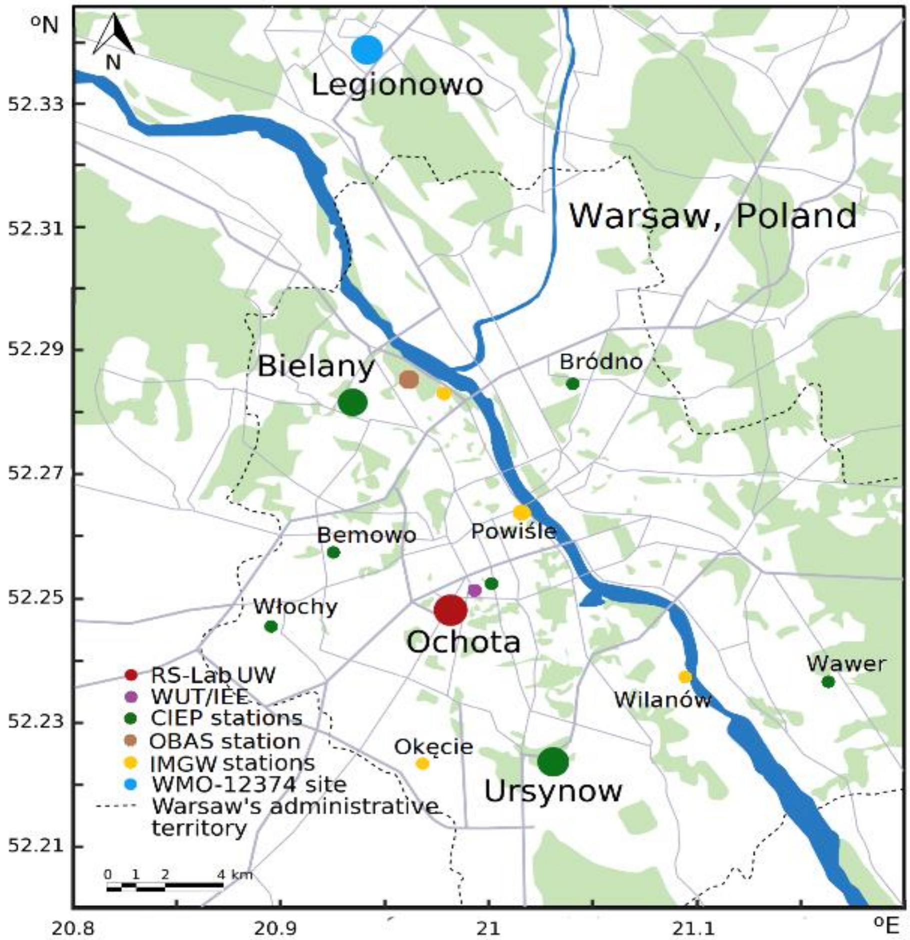

Figure 2. a) *Warsaw map with localization of the WAW (red) and WUT/IEE (violet) supersite in vicinity of University of Warsaw Campus Ochota (red), the CIEP/WIOS monitoring stations (green), the OBAS pollen stations in (brown), the IMGW weather stations (yellow), and the WMO radiosounding station (blue). Approximate locations of the different sites are of less than 12 km horizontal distance from the lidar site. Note that within 2013-2021 not all CIEP stations were operating at the same time. Note that CIEP stations regarded most representative for comparative studies with WAW and WUT/IEE supersite are denoted with large green dots (Bielany, Ursynów).*

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The WAW site belongs and is operated by the Institute of Geophysics at the Faculty of Physics of University of Warsaw. It is currently an ACTRIS site (arosol remote sensing and cloud remote sensing components).

The WAW site (52° 12’ 39’’ N, 20° 58’ 58’’ E, 112 m a.s.l.; www.igf.fuw.edu.pl) comprises research platforms installed on the roof of the university building and at a ground site located at Ochota University Campus (Figure 2). The location of this station, close to several main roads but also to a large park (Pole Mokotowskie), is typical for the agglomeration of Warsaw (2,000,000 population). It is approximately 3 km from the city centre and 4 km from the largest airport in Poland (Warsaw Chopin Airport with 125,000 operations annually). Since 2013, WAW site has been a part of the national measuring web PolandAOD as well as PollyNET lidar network. Since 2015, it has regularly provided EARLINET-ACTRIS lidar observations. Since 2020 it provides regular wind and aerosol lidar, microwave radiometer, disdrometer observations to CLOUDNET-ACTRIS. Since 2018, it provides continuous photometer measurements for AERONET-NASA and since 2023 continuous spectrometer measurements to PGN-NASA. Continuous measurements at this site include standard meteorological parameters, radiation fluxes, in situ and columnar aerosol optical and microphysical properties, and vertical profiles from lidar. These are summarised in Table 1.

The site WUT/IEE is operated by the Warsaw University of Technology in collaboration of the Institute of Environmental Engineering Polish Academy of Sciences.

The WUT/IEE site (52° 13’ 18’’ N, 20° 59’ 33’’ E, 113 m a.s.l.) is currently located very close to the WAW site (see Figure 2) and complements the measurements reported for WAW by adding a complete PM2.5 and PM1 sampling and analysis, with a 24 h resolution, including EC, OC, ions (SO_4^{2-}, NO_3^-, NH_4^+, Cl^-, K^+, Na^+, Mg^{2+}, Ca^{2+}) and elements (Al, Ca, Fe, K, Mg, Na, V, Mn, Ni, Cu, Zn, As, Sr, Cd, Ba, Pb, Cr, Sb, Ti, Br, Co). PM2.5 and PM1 concentrations are determined each day, while chemical composition is determined every second day. The data were obtained during measurement campaigns carried out in 2016 and 2023-2024. The EC data obtained here can be used to obtain the MAC factor to convert absorption measurements at WAW into eBC.

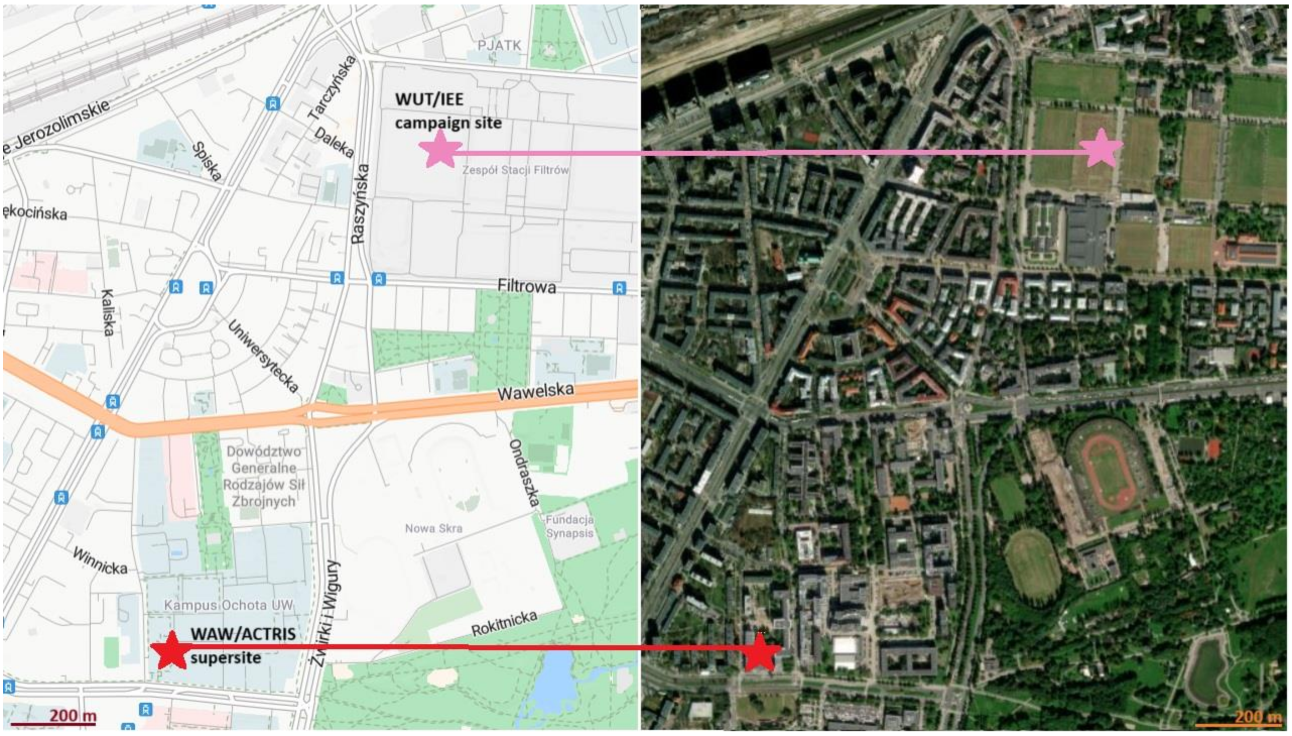

***Figure 2**. b) Warsaw maps with supersite localization of the WAW (red), permament ACTRIS site and WUT/IEE (violet) temporary site operational on the esperimental basis. Both sites will be co-located in the near future.*

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The WAW and WUT/IEE sites, declare the willingness to build a single supersite complementing one another in measurements. However, currently this combined site only partly meets the requirements of RI-URBANS-ACTRIS in terms of in-situ aerosols measurements and novel air quality parameters. If adequately implemented, these measurements might complement the standard measurements of air pollution performed by the Chief Inspectorate for Environmental Protection (CIEP).

The WUT/EE and WAW sites will be located in the same area. The strategic decision has been made, currently formal and logistical arrangements are ongoing. The WUT/IEE site will complement the WAW site by AQ measurements, including PM2.5 and chemical components concentrations.

Air pollutant data with 1-hour resolution (SO_2, PM2.5, PM_{10}, CO, O_3, NOx, NO_2 and NO) from official monitoring stations of CIEP are publicly available via webpage https://powietrze.gios.gov.pl/pjp/current. Three CIEP stations have been operating in automatic mode for more than ten years, and these include the ones listed below. All parameters provided by CIEP are measured and controlled involving methods in accordance with the reference methods specified in Annex VI of the CAFE Directive (2008/50/EC) and arising out of the Act - Environmental Protection Law (Official Gazette 2556/2022).

The CIEP active stations available for Warsaw are summarised below.

- PL0739A (MzWarChrosci), Warszawa (Włochy) ul. Chrościckiego 16/18 - 52.207742N, 20.906073E, Altitude 110 m; Date of starting measurement Jan 1, 2019; Type of station: background; Type of area: urban.

Air pollutants	Averaging period	Measurement mode
SO_2, NO, NO_2, O_3, $PM_{2.5}$, PM_{10}	1-h	Automatic
benzo(a)pyrene in PM_{10}	24-h joined several days	off-line, laboratory
PM_{10}	24-h	Manual

- PL0141A (MzWarWokalna), Warszawa (Ursynów) ul. Wokalna 1 - 52.160772N, 21.033819E, Altitude 102 m; Date of starting measurement Aug 1, 2003; Type of station: background; Type of area: urban.

Air pollutants	Averaging period	Measurement mode
NO, NO_2, O_3, $PM_{2.5}$, PM_{10}	1-h	Automatic
$PM_{2.5}$	24-h	Manual

- PL0140A (MzWarAlNiepo), Warszawa (Ochota) al. Niepodległości 227/233 - 52.219298 N 21.004724 E, Altitude 103 m; Date of starting measurement Aug 1, 2003; Type of station: traffic; Type of area: urban.

Air pollutants	Averaging period	Measurement mode
CO, C_6H_6, NO, NO_2, O_3, $PM_{2.5}$, PM_{10}	1-h	Automatic

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- PL0214A (MzWarAKrzywo), Warszawa (Bemowo) ul. Anieli Krzywoń - 52.228649N 20.917513E Altitude 112 m; Date of starting measurement Jan 1, 2011; Type of station: background; Type of area: urban.

Air pollutants	Averaging period	Measurement mode
SO_2, NO, NO_2, O_3, $PM_{2.5}$, PM_{10}	1-h	Automatic
In PM_{10}: As, Cd, Ni and Pb, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(j)fluoranthene, benzo(k)fluoranthene, dibenzo(ah)anthracene, indeno_123cd_pyrene	24-h joined several days	off-line, laboratory
PM_{10}	24-h	Manual

- PL0143A (MzWarKondrat) Warszawa (Bródno) ul. Kondratowicza 8 - 52.290864N 21.042458E Altitude 85 m; Date of starting measurement Aug 1, 2003; Type of station: background; Type of area: urban.

Air pollutants	Averaging period	Measurement mode
NO, NO_2, O_3	1-h	automatic

- PL0717A (MzWarBajkowa) Warszawa (Wawer) ul. Bajkowa 17/21 - 52.188474N 21.176233E, Altitude 90 m; Date of starting measurement Jan 1, 2019; Type of station: background; Type of area: urban.

Air pollutants	Averaging period	Measurement mode
$PM_{2.5}$, PM_{10}	1-h	automatic
benzo(a)pyrene in PM_{10}	24-h joined several days	off-line, laboratory
PM_{10}	24-h	manual

In comparison to the national monitoring stations, the WAW site provides also long term, continuous information about BC (aethalometer), scattering (nephelometer), bioaerosol (pollen) concentration, and observations with wide range of remote sensing instrumentation (e.g. different aerosol lidars, wind/turbulence lidar, gas spectrometry, aerosol photometry, optical sensor for precipitation). The aerosol measurements are supported by continuous meteorological and radiation measurements and modelling of air-mass dispersion using EULAG model and modelling of boundary layer properties using Code Saturne and PALM model. Backward trajectories are calculated using ZeFir tool, HYSPLIT and Flexpart models.

Regarding the collocation of the WAW supersite (RS-Lab UW in red & WUT/IEE in violet), the sites that we use mainly for comparative research are denoted with LARGE dots in the map of Figure 2, a). Refer to description below.

The CIEP station, refer to green dots on the map in Figure 2, a) in Ochota is the closest one to WAW supersite. However, it is a traffic urban station located at high-traffic spot next to large road junction with tunnel, and thus, it cannot be used for direct comparison. The studies of the CIEP stations (green in Figure 2, a) on representatives for the location of WAW supersite indicate that the CIEP stations on the left-riverbank of Vistula - **Ursynów and Bielany** are a much better choice for comparative studies (e.g. Zawadzka et al. 2013). For specific cases also Włochy and Bemowo stations can be used. Both CIEP stations on the right-riverbank, Bródno and Wawer are found hardly representative.

The OBAS station (in brown, map of Figure 2, a) is equipped with Burkhard pollen trap, very similar type to the one used at WAW supersite. The data form both sites are considered representative for the entire Warsaw.

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As for the IMGW synoptic sites (yellow, map of Figure 2, a), the one regarded most representative is Powiśle, but also Okęcie and Bielany can be well used. Least used is Wilanów site.

Note that there are meteorological stations of UW and WUT directly on WAW site. The WMO 12374 radiosounding site (in blue, map of Figure 2, a) is located in Legionowo, it is one of very few sites typically used as auxiliary information for data analyses at WAW supersite. There are seldom cases for which we replace this information with model data.

As a final comment, it is relevant to note that a financial proposal aiming for a purchase of instrumentation, which would facilitate the integration of the WAW site in the ICOS network, is currently undergoing the second stage of revision.

In addition, trans-national access (TNA) to the WAW site through its current participation in the ATMO-ACCESS TNA programme is very high (in total 15 access applications to use the facility, 9 granted, 4 under avaluation, 2 rejected). The attractivity of research carried out at WAW and high quality of data provided to users allows to expect access to facility be further enhanced.

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Table 1. *List of the measurements implemented at WAW supersite, parameters and time coverage (in black text) and measurements that are not implemented and that should be according to the NAQD in urban supersites (in red text). Shadowed in grey are the measurements related with Art 10 and Annex VII of the NAQD.*

Component	Purpose	Instruments and analyses	Variables	Additional information
In situ aerosols measurements	**Reply NAQD's requests**	Scanning Mobility Particle Sizer (SMPS)	UFP-PNSD from 10 to 800 nm 3938W50-CEN	Need to be purchased
		Condensation Particle Counter (CPC)	UFP > 10 nm; CEN/TS 16976; CEN/TS 17434:2020.	Need to be purchased
		Aethalometer MAGEE AE33	Real time BC (7 wavelengths) type AE33	Since April 2022 (meets RI-URBANS/ACTRIS requirements)
		TEOM 1400a analysers	PM10, PM2.5 concentration - continuous measurement with 1-minute resolution	CEIP monitoring station **Ursynów, Włochy, Bemowo**
		DIGITEL High Volume Sampler DHA-80 (PM2.5, PM1 inlets)	PM2.5, PM1 concentration - continuous measurements with 24-h resolution Chemical analyses of EC, OC, ions: SO42-, NO3-, NH4+, Cl-, K+, Na+, Mg2+, Ca2+, elements: Al, Ca, Fe, K, Mg, Na, V, Mn, Ni, Cu, Zn, As, Sr, Cd, Ba, Pb, Cr, Sb, Ti, Br, Co – analyses every second day. The EC data obtained here can be used to obtain the MAC factor to convert absorption into eBC.	Measurements currently taken at WUT/IEE from 1 April 2023 to 30 June 2024 (may be prolonged) Need to be fix or discontinuous
		Organic speciation	Levoglucosane, BaP, PaH, among others	Need to be fix or discontinuous Using fractions filters from DIGITEL
		Oxidative Potential	Using DTT and AA assays	Need to be fix or discontinuous Using fractions filters from DIGITEL
	Available for supporting interpretations	Polar nephelometer AURORA 4000 Polar nephelometer AURORA 4000 <u>with ACS 1000 chamber</u>	Real-time light scattering in a sample of ambient air at three wavelengths: 450, 525, and 635 nm (blue, green, and red) – reference instrument Real-time light scattering in a sample of ambient air at three wavelengths: 450, 525, and 635 nm (blue, green, and red) - humidity-modified aerosol with use of ACS1000 chamber	Since April 2022 (meets RI-URBANS/ACTRIS requirements) Since April 2022 (meets RI-URBANS/ACTRIS requirements
		Photoacoustic Extinctiometer PAX	Aerosol extinction and absorption at 552nm and 870 nm (2 instruments)	Since 2020, used so far mainly during campaigns
		Burkard Volumetric Spore Trap VPPS*2010 with microscope	Pollen measurements (manual reading of pollen types concentration number)	Since January 2023
		UAV MatriceDJ - instrumented	Instrumented with aethelometer AE51, radiosounding system RS41, particle sizer SPS30, plus set of radiometersy, payload 1-4kg	Used for campaigns
		Burkard Volumetric Spore Trap VPPS*2010 with microscope	Pollen measurements (manual reading of pollen types concentration number)	OBAS pollen monitoring site Since January 2024
Gas measurements	**Reply NAQD's requests**	O_3 analyser (MLU 400 UV absorption)	Not available but data from the closest CEIP monitoring station can be used	CEIP monitoring station **Ursynów, Włochy, Bemowo**

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		NOx, NO_2 analyser chemiluminescence	Not available but data from the closest CEIP monitoring station can be used	CEIP monitoring station **Ursynów, Włochy, Bemowo**
		SO_2 analyser ultraviolet absorption	Not available but data from the closest CEIP monitoring station can be used	CEIP monitoring station **Włochy, Bemowo**
		CO analyser spectroscopy	Not available but data from the closest CEIP monitoring station can be used	CEIP monitoring station
		NH_3 measurements, passive samplers	Recommended	Implement measurements with weekly or 10 days resolution
		VOCs with GC-MS	Recommended	Implement measurements
	Available for supporting interpretations	Pandora S2 spectrometer (remote sensor)	Automated observations of columnar trace gases Ozone, Sulfur Dioxide, Nitrogen Dioxide, Formaldehyde, Water Vapor, and others; Spectral Range 270 - 530nm and 400 - 900nm Spectral Resolution 0.6nm/UV and 1.1nm/VIS	Since October 2023, data provision to PGN-NASA
Meteorology	Available for supporting interpretations	T (only at 20m)		since 2007
		RH (only at 20m)		since 2007
		Atmospheric Pressure (only at 20m)		since 2007
		WS and WD ultrasonic sensors (only at 20m)	Anemometer KH20	since 2007
		OTT Parsivel disdrometer (only at 20m)	Laser Weather Sensor disdrometer for comprehensive measurement of all precipitation types	since 2013, data provision to CLOUDNET-ACTRIS
		VisiSize D30 Shadowgraph system (only at 20m)	Measurements of cloud particles number and shape	Since 2018
		Sky camera ALCOR	24/7 high resolution whole sky watch with digital camera	Since 2020
		Microwave Radiometer HATPRO	Measurement of meteorological profiled of RH and T, and columnar LWP	Since 2019, data provision to CLOUDNET-ACTRIS
		Radiosounding system S92SPG or RS42 with data receiving station	RS92SPG profiling with meteorological balloon	Used during campaigns
		Radiosounding system WMO#12374	Twice a day regular sounding RS92SPG profiling run in near-by IMGW-BIP site in Lagionowo (25km North of WOS site), online data visualisation via Uni Wayoming RS Server	IMGW-BIP synoptic site
Radiation budget (*passive remote sensors*)	Available for supporting interpretations	Kipp&Zonen CNR4 Net Radiometer with Sun-trecker STR22/Solys2	Direct and diffuse radiation	since 2008
		Pyranometers	CMP22, CGR4	since 2008
		Sun photometer CIMEL CE318	(several channels within 340–1640)	Since 2018 data provision to AERONET-NASA
		Sun/Lunar photometer CIMEL CE318-T	(several channels within 340–1640) day/night capability	Since January 2024 data provision to AERONET-NASA

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		Shadowband radiometer MFR-7	Radiation at 415, 500, 610, 675, 870, 940 nm, similar to photometer observations	Since 2018
		Hand-held sun photometer MICROTOPS II	(5 channels within 340–1020), 2 instruments available	Used during campaigns
		Spectrometer PandoraS2	hyperspectral observations from 270nm to 900nm of direct sun, moon, and scattered skylight	Since October 2023 data provision to PGN-NASA
Radiation budget (*active remote sensors*)		Mie-Raman polarization lidar PollyXT-UW	Real time range information on aerosol structure in the troposphere and lower stratosphere; within 1-2 days aerosol extinction, backscattering, depolarization, and water vapour profiles; information of AOD and AE in layers (including boundary later), working at 8 channels 355(s), 387, 407, 532(s), 607, 1064 nm, min. height of profile 450m	Since 2013, data provision to EARLINET-ACTRIS
		Near-range Mie-Raman lidar NARLa	Real time range information on aerosol structure in the lower troposphere; within 1-2 days aerosol extinction and backscattering; information of AOD and AE in layers (including boundary later), working at 4 channels 355, 387, 532, 607 nm, min. height of profile 80m	Since 2015, data provision to EARLINET-ACTRIS
		Doppler Lidar HALO	Wind speed and directions profiles in boundary layer	Since 2021, data provision to CLOUDNET-ACTRIS

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4.2.2. WRC: Wrocław - the supersite at University of Wrocław

Institution: University of Wrocław, Institute of Geography and Regional Development, Department of Climatology and Atmosphere Protection
Site name: WRC/ACTRIS
Contact: Anetta Drzeniecka-Osiadacz (anetta.drzeniecka-osiadacz@uwr.edu.pl).
Location: 51° 06′ 20′′ N, 17° 05′ 20′′E, 120 m a.s.l.

The city of Wrocław (area 293 km^2), capital of Lower Silesia province, is located in southwest Poland (51°N, 17°E) at approx. 120 m a.s.l., close to the WSW border of Poland (Figure 1). As of 2022, the official population of Wrocław is 673,923 making it the third largest city in Poland, and it is also a hub of Wrocław's agglomeration with around 1 million inhabitants. The area of the city has little differentiation in the terrain morphology, and the altitude varies from 105 to 148 m a.s.l. Wrocław lies on the Oder River and its four tributaries, which form the lowest parts of the city and are also its main ventilation channels. Majority of the land cover of Wrocław consists of green areas (forests, grasslands, wastelands and parks) and agricultural areas which cover over 60 % of the city area. The other dominant elements of landscape are: industrial areas (13 %) and built-up areas (17 %).

The climate of Wrocław is moderate, transitional between maritime and continental conditions. Winds from the western sector are dominant—about 51 % of occurrence. The mean annual temperature reaches 9.7°C (1991 – 2020) (in 1971–2000 it was 8.7°C) with a minimum in January (0.0°C) and maximum in July (19.7°C). The annual precipitation sum is almost 541 mm on 156 days with precipitation. The highest monthly sum of precipitation is observed in July (91.4 mm), and the lowest in February (25.6 mm) (Normy, www.klimat.imgw.pl). The location of Wrocław in the relative depression of the valley of the river and in the foreland of the Sudety Mts makes the city thermally privileged. Additionally, a large bioclimatic diversity and the well-developed phenomenon of urban heat-island can be observed.

Over the recent years, the city is rapidly developing and expanding. Nowadays, Wrocław is the second-wealthiest of the large cities in Poland after Warsaw. A number of other smaller and greater business enterprises operate in the city. The industry manufactures buses, railroad cars, home appliances, chemicals, and electronics (such as WAGO Kontakttechnik, Siemens, Bosch, Whirlpool Corporation, Nokia Networks, Volvo, HP, IBM, Google, Opera Software, Bombardier Transportation, WABCO). Close to the city border in the so-called “Economic Zone” are LG (LG Display, LG Electronics, LG Chem, LG Innotek), Dong Seo Display, Dong Yang Electronics, Toshiba, etc. Wrocław is a major transport hub, situated at the crossroad of many routes linking Western and Central Europe with the rest of Poland. European, national and provincial roads (e.g. A4, A8 bypass, S5, S8 and many others) run through Wrocław. Traffic congestion is an important problem in Wrocław; e.g. in early 2020 it was ranked as the fifth-most congested city in Poland, and 41st in the world. Moreover Wrocław, as many regions in Poland, suffers from specific environmental issues related to air quality. Air quality standards for e.g. PM_{10} and $PM_{2.5}$ are exceeded and the main reason is emission of pollutants from residential combustion due to fossil fuel burning.

The proposed WRC supersite is located in a suburban environment in the eastern end of the city in an open field belonging to the University of Wrocław (Figure 3). The instrumentation implemented in this site covers surface air pollutants (conventional and advanced parameters), radiative measurements and meteorology, covering most of STs measured in the urban supersites of RI-URBANS/ACTRIS, which coincide with those requested by Art10 of the NAQD draft. Figure 4 shows details of the instrumentation of the WRC supersite. The list of measurements implemented, parameters and time coverage are listed in Table 2; the red text highlights the measurements which are not yet implemented and which should be deployed according to the NAQD and the RI-URBANS/ACTRIS guidance on urban supersites.

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Figure 3. *Location of the WRC supersite in Wrocław.*

Figure 4. *Some of the instrumentation implemented at the WRC supersite, listed in Table 2.*

The WRC station of University of Wrocław meets the requirements of RI-URBANS-ACTRIS in terms of in-situ aerosols measurements, therefore can complement the standard measurements of air pollution performed by Chief Inspectorate for Environmental Protection (CIEP).

In comparison to the national monitoring stations, the WRC station provides additional information on UFP_PNSD, BC, and bioaerosols concentration (automatic, near real-time). Moreover, the laboratory of the University of Wrocław on Cybulskiego 32 Str is equipped with CRDS Picarro G2201-i system with attached additional analyzers (CM and AutomateFX) which allow measuring: (i) GHGs (CO_2 and CH_4) concentration and carbon isotopes composition ($\delta^{13}C$) from both ambient air gases collected to Tedlar bags; (ii) carbon isotope composition ($\delta^{13}C$) from PMx (PM1/PM2.5/PM10) collected on Q filters.

Three CIEP's stations have been operating in automatic mode for more than ten years, and these include the ones listed below (Figure 5).

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- PL0194A (DsWrocWybCon) - J.Conrada-Korzeniowskiego 18 St Wrocław – 51.129378N, 17.02925E, urban background air quality monitoring station.

Air pollutants	Averaging period	Measurement mode
SO_2, C_6H_6, CO, NO, NO_2, O_3, $PM_{2.5}$, PM_{10}	1-h	Automatic
Heavy metals: As, Ni, Kd, Pb, VOCs: benzo(a)pyrene, benzo[a]anthracene, benzo(b)fluoranthene, benzo(j)fluoranthene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene	24-h	off-line, laboratory
PM_{10}	24-h	Manual

- PL0197A (DsWrocAlWisn) - Wiśniowa/ Powst. Śląskich St, Wrocław, 51.086225N, 17.012689E, traffic air quality monitoring station.

Air pollutants	Averaging period	Measurement mode
CO, NO, NO_2, NOx, PM2.5	1-h	Automatic

- PL0193A (DsWrocBartni) – Bartnicza St, Wrocław, 51.115933, 17.141125, suburban background air quality monitoring station.

Air pollutants	Averaging period	Measurement mode
NO, NO_2, NOx, O_3	1-h	Automatic

There are also two CIEP stations that perform measurements in manual mode.

- PL0196A (DsWrocOrzech) – Orzechowa St, Wrocław, 51,077525. 17,042817, urban background air quality monitoring station.

Air pollution	Averaging period	Measurement mode
PM10, benzo(a)pyrene,	24 h	Manual and off-line laboratory

- PL0490A (DsWrocNaGrob) – Na Grobli St, Wrocław, 51,103456, 17,059225, urban background air quality monitoring stations.

Air pollution	Averaging period	Measurement mode
PM10	24 h	Manual

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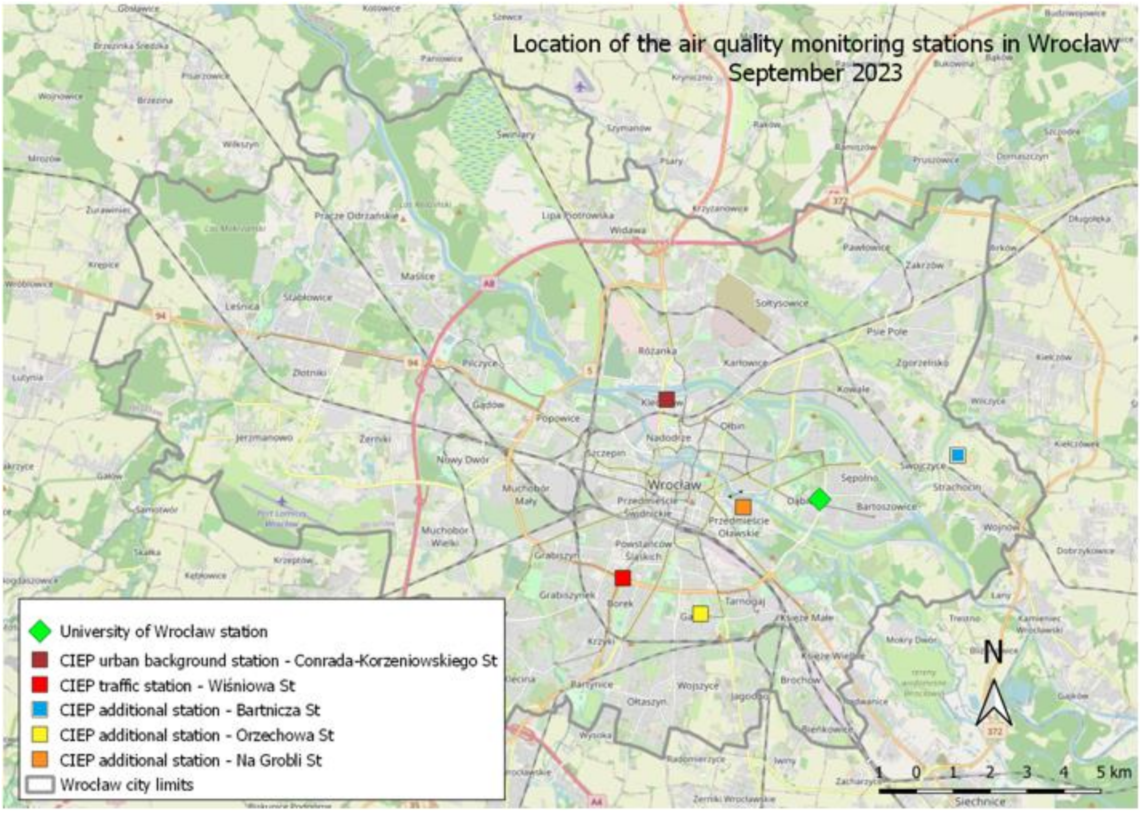

Figure 5. *Location of air quality measuring stations in Wrocław, WRC is indicate as green diamond.*

As a final comment, it is relevant to note that trans-national access to the WRC station is expected to be enhanced through its current participation in the ATMO-ACCESS programme.

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Table 2. *List of the measurements implemented at WRC supersite, parameters and time coverage (in black text) and measurements that are not implemented and that should be according to the NAQD in urban supersites (in red text). Shadowed in grey are the measurements related with Art 10 and Annex VII of the NAQD.*

Component	Purpose	Device	Variables	Additional information
In situ aerosols measurements	**Reply NAQD's requests**	Scanning Mobility Particle Sizer (SMPS) 3938W50-CEN	PNSD from 10 to 800 nm	Since December 2022 (meets RI-URBANS/ACTRIS requirements)
		Aethalometer MAGEE AE43	BC concentration	Since December 2022 (meets RI-URBANS/ACTRIS requirements)
		TEOM 1400a analysers	PM10 (at height of 15 m a.g.l.), PM2.5 concentration (at height of 15 m a.g.l. and 4 m.a.g.l)- continuous measurement with 1-minute resolution	Since 2013
		COMDE-DERENDA Low Volume / Medium Volume Sampler LVS / MVS (TSP, PM10, PM2.5, PM1 inlets) and DIGITEL High Volum Sampler (PM2.5 inlets)	PMx levels and off-line chemical analysis (metals, anhdrosugars, ions (anions and cations)/ CRDS Picarro G2201-I (CM - combustion module, AutomateFX, SSIM - small sample isotope module). Recommended to add OC and EC ToT analyses for PM speciation and for in situ conversion of BC into eBC Recommend adding PAHs, including BaP Recommended to ad Oxidative Potential analyses Recommended organic PM speciation	Since 2022 (only during measuring campaigns) Chemical analysis is carried out on a request by Institute of Environmental Engineering - Polish Academy of Sciences (Supporting Lab in ACTRIS-Poland) Need to be fix or discontinuous
		Oxidative Potential	Using DTT and AA assays	Need to be fix or discontinuous Using fractions filters from DIGITEL
	Available for supporting interpretations	Aerodynamic Particle Sizer APS 3321 (TSI)	PNC and PM 0.5 to 20µm (aerodynamic sizing)	Since December 2022 (meets RI-URBANS/ACTRIS requirements)
		Polar nephelometer AURORA 4000	PM, Real-time light scattering in a sample of ambient air at three wavelengths: 450, 525, and 635 nm (blue, green, and red)	

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		DustTrak™ II Aerosol Monitor 8532/ DustTrak™ DRX Aerosol Monitor 8533EP	Optical analysers for PMx concentration measurements. Used for mobile measurements	The equipment used for mobile measurement to assess the spatial distribution of PM across the city
		UAV equipped with measuring head	Horizontal and vertical temperature, humidity, PM2.5 concentration/ 3D measurements	Vertical and horizontal distribution of PM concentration above canopy layer up to 350 m a.g.l.
		SwisensPoleno Jupiter	Allergic pollen measurements in real time	Since September 2023
		Burkard Volumetric Spore Trap	Allergic pollen measurements by means of microscopic analysis	Since 2018/ UWr has a second bioaerosols measurement station that has been operating for over 15 years
Gas measurements	**Reply NAQD's requests**	O_3 analyser (MLU 400 UV absorption)	Continuous O_3 concentration measurements	Since 2018
		NOx, NO_2 analyser chemiluminescence	Continuous NO_x/NO_2 concentration measurements	Since December 2024
		SO_2 analyser ultraviolet absorption	Not available but data from the closest CEIP monitoring station can be used	CIEP monitoring station
		CO analyser spectroscopy	Not available but data from the closest CEIP monitoring station can be used	CIEP monitoring station
		NH_3 measurements, passive samplers	Recommended	Implement measurements with weekly or 10 days resolution
		VOCs with GC-MS	Recommended	Implement measurements
		Picaro G2201-I for stationary measurements	Measurements of GHG (CO_2 and CH_4) concentration and d13C of both gases gathered in Tedlar bags	Since 2017

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Meteorology	Available for supporting interpretations	T [°C] (at different levels above the ground: 0m, 5 cm, 0,5 m, 2 m, 5 m, 10m, 15m	Air temperature measured according to meteorological standards inside standard Stevenson's screen, 2 m a.g.l. (Vaisala HMP 45C temperature and relative humidity probe) Vertical profile of air temperature at actinometric tower (pt100 sensors with portable screens located at 0.5, 2.0, 5.0, 10.0, 15.0 m a.g.l.) Ground level temperature (pt100 sensors at ground level (0 cm a.g.l.) and 5 cm a.g.l.)	1-min resolution
		RH [%]	Relative humidity measured according to meteorological standards inside standard Stevenson's screen, 2 m a.g.l. (Vaisala HMP 45C temperature and relative humidity probe)	1-min resolution
		Atmospheric pressure [hPa]	Barometric pressure measured inside an air-conditioned measuring container, sensor is located 2 m a.g.l. (Vaisala PTA 427 pressure probe)	1-min resolution
		WS [m/s] and WD [°0] measurements	Wind speed (WS) and wind direction (WD) measured at the top of the mast installed on Observatory actinometric tower (17 m a.g.l.) with use of Gill WindSonic1-L 2-D Sonic Wind Sensor	1-min resolution
		Precipitation	OTT Parsivel 2 disdrometer (measurement of precipitation intensity [l/h], sum [mm], precipitation types (rain, drizzle, hail etc., with use of synoptic code), visibility [m], up to 3000 m) Additionally, standard manual measurements of daily precipitation sums are made using a standard Hellman rain gauges (2 rain gauges at 1 m a.g.l. 1 rain gaure at ground level)	1-min resolution
		Standard meteorological measurements	Manual and automatic measurements of crucial weather parameters (T [°C], RH [%}, water vapour pressure [hPa], atmospheric pressure [hPa], wind speed and direction at 17 m a.g.l., sunshine duration, solar radiation [W/m^2], precipitation sum [mm])	Since 1946
Radiation budget	Available for supporting interpretations	Sunshine duration	Kipp&Zonen Sunshine Duration Sensor CSD3, supplemented with a Campbell-Stokes heliograph, located at the top of Observatory actinometric tower, 15 m a.g.l.	1-min resolution
		Radiation budget	Kipp&Zonen CNR4 Net Radiometer, 1.,5 m a.g.l.	1-min resolution

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		Short wave solar radiation	2 x Kipp&Zonen CMP11 sensor (measurement of total and diffuse solar radiation), located at the top of Observatory actinometric tower, 15 m a.g.l.	1-min resolution
		UV	UV-B sensor Yankee Env. Sys., located at the top of Observatory actinometric tower, 15 m a.g.l.	1-min resolution
Remote sensing measurements	Available for supporting interpretations	Doppler sodar 1DDS	Sodar provides information on vertical structure of lower part of ABL based on backscattered coefficient of acoustic wave, and vertical wind speed based on Doppler effect	1 minute resolution, since 1984
		Sun and lunar photometer CE3818T	Several channels within 340–1640 nm day/night capability	Since June 2023 (meets ACTRIS requirements)
		High power aerosols lidar	High power aerosols lidar (elastic channels: 532nm, 355nm, Raman channels: 387nm, 408nm; depolarized channel: 532nm) will be launched at the end of this year	Lidar will be lunched in the beginning of 2024 (will meet ACTRIS requirements)

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4.2.3. GZM: Zabrze - the supersite at Institute of Environmental Engineering Polish Academy of Sciences

Institution: Institute of Environmental Engineering of the Polish Academy of Sciences
Site name: GZM
Contact: Barbara Błaszczak: (barbara.blaszczak@ipispan.edu.pl)
Location: 41-819 Zabrze, ul. M. Skłodowskiej-Curie 34 (50° 19’ 01’’ N, 18° 46’ 16’’ E, 245 m a.s.l.)

Górnośląsko-Zagłębiowska Metropolia - Metropolis GZM comprises 41 cities and communes (Figure 6) distributed in a close or even adjoin way, with a total area of 2,500 km^2, where 2.1 million residents live, with 270,000 companies and enterprises, generating approx. 8 percent of our country’s GDP, located in the centre of the Silesian Province. The Metropolis GZM is Poland’s first metropolis.

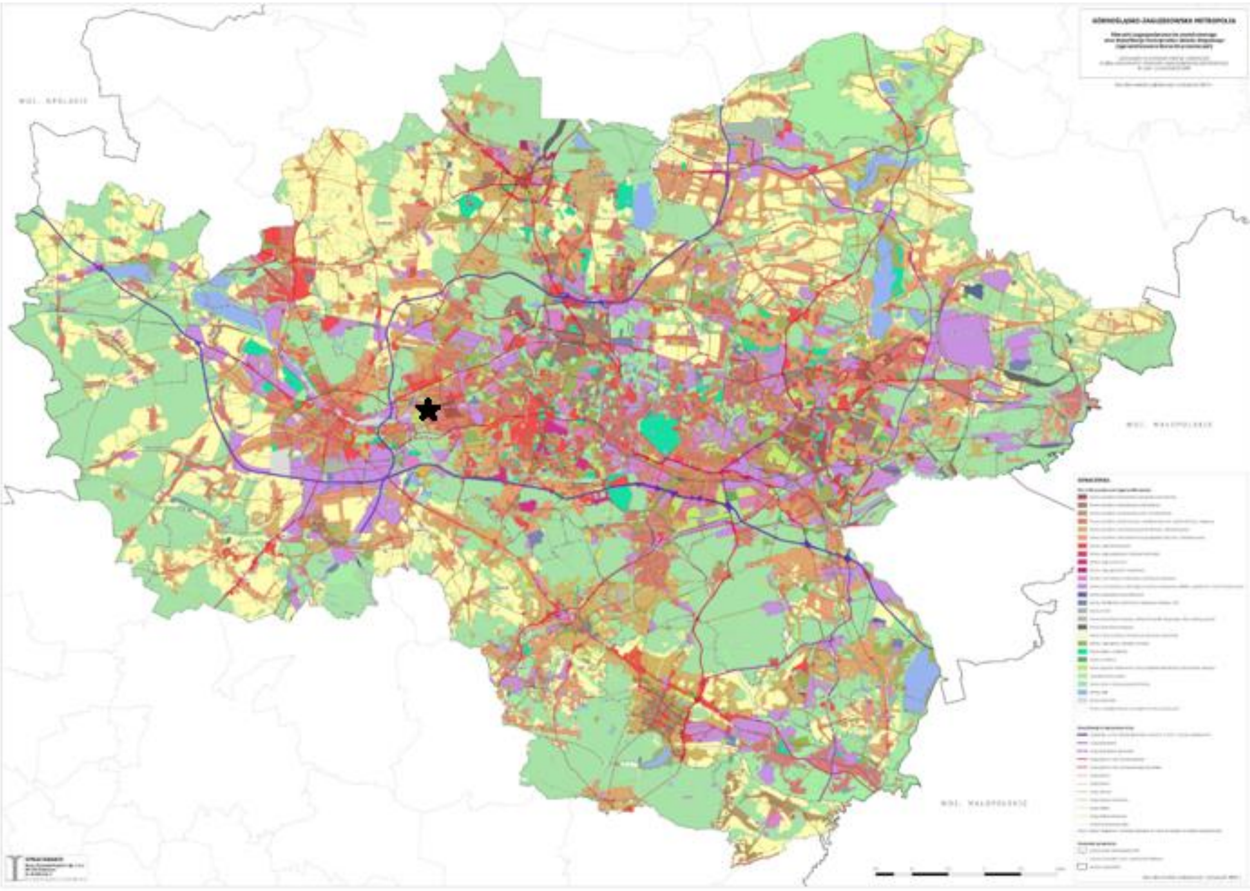

Figure 6. *GZM Metropolis, location of IEE PAS supersite is marked with black star.*

The GZM area belongs to areas with high anthropic pressure associated with the concentration of heavy industry, mining, coal power engineering and numerous main transit routes with high traffic. In GZM there are 7 air quality monitoring stations operating in the national monitoring network of the Chief Inspectorate of Environmental Protection (CIEP).

Measurements of air pollution have been carried out using various methods and measurement networks since the 60s of the twentieth century. Three CIEP’s stations have been operating in automatic mode for more than ten years, and these include the ones listed below (Figure 7). The research station of the institute is located in Zabrze in the direct headquarters of the CIEP monitoring station (Figure 7).

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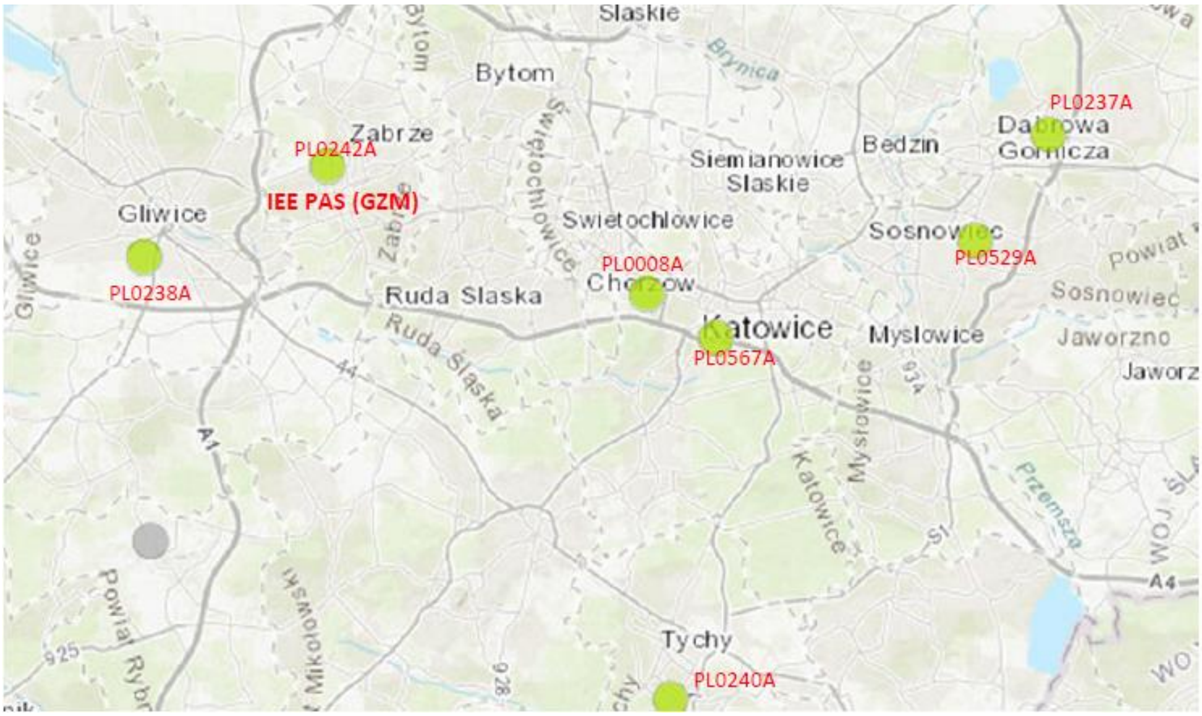

Figure 7. *Location of air quality measuring stations in GZM Metropolis, note that one of them is co-located to IEE PAS supersite.*

Below is given a short list and description of CIEP stations in the GZM Metropolis:

- SlKatoPlebA4, PL0567A, Katowice, ul. Plebiscytowa/A4, WGS84 - 50,24679N 19,019469E, Type of area: traffic station.

Air pollutants	Averaging period	Measurement mode
SO_2, CO, NO, NO_2, PM2.5, PM10	1-h	Automatic

- SlTychyTolst, PL0240A Tychy, ul. Tołstoja 1, WGS84 - 50,099903N 18,990236E

Air pollutants	Averaging period	Measurement mode
SO_2, NO, NO_2, PM10	1-h	automatic

- SlKatoKossut, PL0008A, Katowice, ul. Kossutha 6, WGS84 - 50,264611N, 18,975028E
  Type of station: background, Type of area: urban background

Air pollutants	Averaging period	Measurement mode
SO_2, NO, NO_2, O_3, $PM_{2.5}$, PM_{10}	1-h	automatic
In PM_{10}: As, Cd, Ni and Pb, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(j)fluoranthene, benzo(k)fluoranthene, dibenzo(ah)anthracene, indeno_123cd_pyrene	24-h joined several days	off-line, laboratory
$PM_{2.5}$, PM_{10}	24-h	manual

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- SlDabroTysia, PL0237A, Dąbrowa Górnicza , ul. Tysiąclecia 25 a, WGS84 - 50,329111N, 19,231222E, Type of area: urban background.

Air pollutants	Averaging period	Measurement mode
Benzene, CO, SO_2, NO, NO_2, O_3, PM_2 PM_{10}	1-h	automatic
In PM_{10}: As, Cd, Ni and Pb, benzo(a)pyrene	24-h joined several days	off-line, laboratory
PM_{10}	24-h	manual

- SlGliwicMewy, PL0238A, Gliwice, ul. Mewy, WGS84 - 50,279481N 18,655736E

Air pollutants	Averaging period	Measurement mode
Benzene, SO_2, PM_{10}	1-h	automatic
$PM_{2,5}$	24-h	manual

- SlSosnoLubel, PL0529A, Sosnowiec, ul. Lubelska 51, WGS84 - Φ 50,285956 λ 19,184399

Air pollutants	Averaging period	Measurement mode
NO, NO_2, PM_{10}	1-h	automatic

- SlZabSkloCur, PL0242A, Zabrze, ul. M. Curie-Skłodowskiej, WGS84 - 50,3165N 18,772375E, urban background air quality monitoring station.

Air pollutants	Averaging period	Measurement mode
SO_2, CO, NO, NO_2, O_3, PM_{10}	1-h	automatic
benzo(a)pyrene,	24-h	off-line, laboratory
PM_{10}	24-h	manual

The Zabrze (GZM) supersite can be collocated with the CEIP site **PL0242A.** The GZM-IEEPAS research station conducts constant measurements of PM_1, $PM_{2.5}$, PM_{10}, TSP, eBC, UFP, TNOx (NH3, NO, NO_2), continuous measurement of C-sum in aerosols, mercury speciation in the gas and aerosol phases. Furthermore, as part of research projects, analyses of daily samples of selected PM fractions are carried out, in particular PM_1 in the field of OC / EC, ions, etc., depending on the implemented project.

In - situ chemical analyses are performed at the Institute's accredited Research Laboratory (certificate number AB 950). The Research Laboratory of the IEE PAS in Zabrze operates in a system in accordance with the PN-EN ISO/IEC 17025:2018-02 standard. The Laboratory performs analyses including the determination of organic compounds, sugars, ions and metals.

The station is also working on the use of low-cost sensors in indicator measurements.

The measuring plot is adapted to intercalibration of equipment for testing atmospheric pollution.

IEE PAS is consorciant of the ACTRIS-Poland with supportive role to the ACTRIS National Facilities in Poland.

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Table 3. *List of the measurements implemented at GZM supersite, parameters and time coverage (in black text) and measurements that are not implemented and that should be according to the NAQD in urban supersites (in red text). Shadowed in grey are the measurements related with Art 10 and Annex VII of the NAQD*

Component	Purposes	Device	Variables	Additional information
In situ aerosols measurements	Reply NAQD's requests	UFP 3031(TSI)	20nm- 200 nm (aerodynamic sizing) Recommended to switch to the RI-URBAN/ACTRIS standard	Measurement campaigns Recommended continuous
		TEAOM 1400a analysers	PM2.5 concentration - continuous measurement with 1-minute resolution	Since 2013
		PM optical monitor PALLAS FIDA	PM, Real time monitor pM1, PM2,5, PM4 PM10, TSP	Since April 2022
		BC monitor – MAAP 5012 Aethalometer MAGEE AE-33	BC BC Concentration	2009 Since April 2024
		MCZ, COMDE-DERENDA Low Volume / Medium Volume Sampler LVS / MVS (TSP, PM10, PM2.5, PM1 inlets)	PM1 PM2,5 PM10	measuring campaigns Need to be fix or discontinuous
		HVS Digitel AG	PM1, PM2,5 PM10	measuring campaigns) Need to be fix or discontinuous
		PM2.5 speciation	OC/EC, elements, HAP, anions and cations, monosacharids (LG, MM, GT)	Need to be fix or discontinuous Using fractions filters from DIGITEL
	Available for supporting interpretations	OPS - TSI 3330 (0,3-10µm)	(0,3-10µm)	Measurement campaigns
		TOT analyser	Total carbon analysers – Aerosols	From 2023
		Decati, end ELPI 13 stage impactors	Separations 7nm- 10 µm aerosols	Measuring campaigns
Gas measurements	Reply NAQD's requests	VOCs with GC-MS	Recommended	Implement measurements
		TNO, NO, NO_2 analyser chemiluminescence	Aerodyne	Since 2022
		Tekran 2537 with 1130 i 1135,	Speciation Hg in gas and aerosols	
		NH_3 analyser chemiluminescence Add passive samplers	Aerodyne	Since 2022 add passive samplers' measurements with weekly or 10 days resolution
Meteorology		Vaisala, GILL, DAVIS PRO +	Wind speed, direction, Rh, T, solar rad. UVB	
Depositions		EIGENBRODT	Wet deposition, or total depositions	

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4.2.4. PL-KRK: Kraków – the supersite at AGH University of Kraków

Institution: AGH University of Kraków
Site name: PL-KRK
Contact: Mirosław Zimnoch: (zimnoch@agh.edu.pl)
Location: 30-059 Kraków, Al. Mickiewicza 30 (50° 04’ 01’’ N, 19° 54’ 47’’ E, 200 m a.s.l.)

Kraków is the second largest Polish city located in Lesser Poland voivodeship (Southern Poland) with a total area of 327 km^2 and almost 1 million residents. It is located in the valley of the Vistula River passing the city from west to the east. Characteristic features of the city landscape include densely built central districts, a historical city centre, an extensive industrial compound in the eastern part, and loosely built outskirts (Figure 8). The population density in the districts varies strongly from less than a thousand inhabitants per square km, to more than ten thousand.

The typical structure of air pollutants emission sources includes domestic heating, transport, energy production and industry. In recent years, the city authorities undertook actions to reduce pollutant emissions in the city, but due to the city's location in a valley, a significant contribution still comes from emission sources located in the surrounding villages, where coal stoves are still the dominant method of heating. With prevailing westerly circulation, Kraków area is also under substantial influence of large coal mining and industrial district (Upper Silesia) located approximately 60 km west of the city.

Kraków is located in a temperate climate zone, in an area where maritime air masses coming with the westerly flow acquire more continental characteristics. Average annual air temperature based on the 30-year climatology of 1991-2020 at the World Meteorological Organisation (WMO) weather station Kraków-Balice (WMO no. 12566) is 8.9 °C with maximum temperatures occurring in July (climatological mean daily maximum temperature of July equal to 25.3°C) and minimum in January (climatological mean minimum daily temperature of January equal to -4.7°C). Annual precipitation reaches 673 mm with higher amounts during the summer and lower during the winter. The characteristic features of the local climate are generally weak winds (annual average around 2.7 m/s) and frequent inversions, sometimes extending over several days, particularly during winter season.

Since the 80s of the twentieth century, the measurements of greenhouse gases (CO_2, CH_4, isotopic composition) and air pollution (PM concentration, elemental and chemical composition, gas pollutants) have been carried out using various methods by AGH University of Kraków. For consideration of urban supersite, we propose a nearby-located two sites (Figure 8; A (stationary observations) and B (balloon profiling).

The PL-KRK stationary research station of the AGH University of Kraków is located in point A (Figure 8) on the roof of Faculty of Physics and Applied Computer Science building. The research is conducted in collaboration of three AGH units:

- Environmental Physics Group, Faculty of Physics and Applied Computer Science (FPACS) – contact: Mirosław Zimnoch (zimnoch@agh.edu.pl)
- Biomedical and Environmental Research Group, Faculty of Physics and Applied Computer Science (FPACS) – contact: Lucyna Samek (samek@agh.edu.pl)
- Interdisciplinary Research Team on Environmental Stressors Using Circular Epidemiology, Faculty of Energy and Fuels (FEF) – contact: Katarzyna Styszko (styszko@agh.edu.pl)

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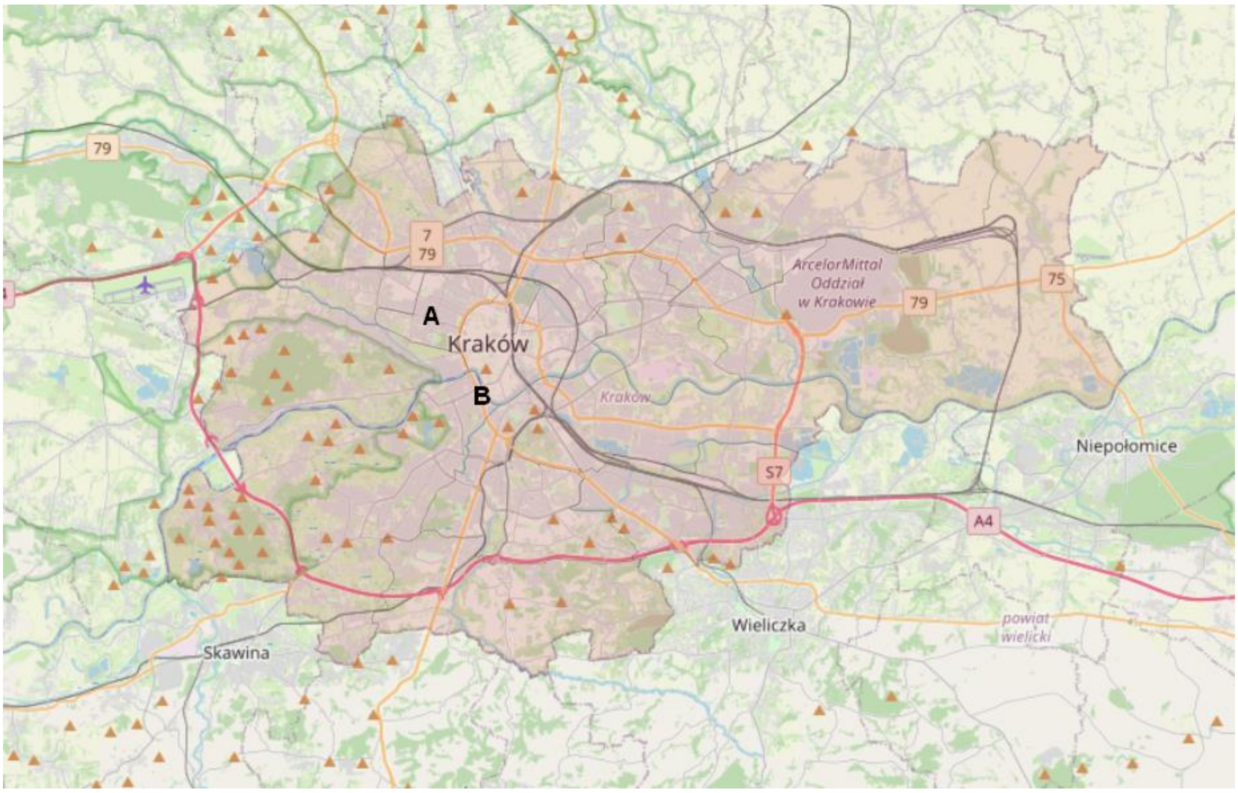

Figure 8. *An overview of Kraków city area with the location of two regular observation points. (A) stationary platform at AGH University of Kraków campus proposed as location for KRK urnban supersite, (B) Tethered touristic balloon site with AGH instrumantation.*

The PL-KRK station is currently not foreseen for contributing to ACTRIS-ERIC. However, regarding the plans of Poland for joining the ICOS-ERIC research infrastructure, this station is indicated as an urban station within the planned Poland contribution to ICOS.

The PL-KRK mobile station (Figure 8, point B) is operated on tethered touristic balloon in cooperation with company Balon Widokowy Sp. z o.o. This station is dedicated for quasi-continuous or campaign-based monitoring of the vertical structure of urban boundary layer (meteorology, PM_{10}, CO_2/CH_4 mixing ratios.

Note that AGH has also capacity for conducting mobile surface or 3D mapping campaigns using off-road car or drone systems equipped with different sensors (see Tables 4-6).

Table 4. *AGH campus, Kraków, ul. Reymonta 19, 50° 04’ 01’’ N, 19° 54’ 47’’ E Type of area: urban background; compare Figure 8, A.*

Air pollutants and GHG’s	Temporal resolution	Measurement mode
CO2, CH4, (Picarro instrument)	1 second	Automatic
CO2 flux (eddy covariance)	30 min	Automatic
$^{13}CO_2$, $^{14}CO_2$	1 month	Automatic
PM_{10}, SO_2, NO_x, CO, SO_2	1 minute	Automatic
PM_{10}, $PM_{2.5}$, PM_1 composition	1 day	manual, campaign-based

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Table 5. *Kraków balloon, 30-302 Kraków, ul. Konopnickiej 28, 50º 02’ 45’’ N, 19º 56’ 10’’ E Type of station: vertical profiling of the boundary layer (0-280 m a.g.l.); compare Figure 8, B.*

Air pollutants	Temporal resolution	Measurement mode
PM_{10}	1 second	automatic
Multifaction PM (0.2-50 μm) with typology (LOAC)	10 second	automatic
CO_2, CH_4	1 second	manual campaign-based

The AGH Kraków research station conducts continuous measurements of PM10, SO_2, NO_x, CO, O_3, CO_2, CH_4, meteorology, radiation balance, CO_2 surface flux.

In addition, as part of research projects, analyses of daily samples of selected PM fractions are carried out, in particular PM1, PM2.5 and PM10, in the field of eBC, elements, ions, PAHs and their hydroxy derivatives etc., depending on the implemented project. Moreover, measurements of oxidative potential of PM and levoglucosan concentration can be implemented. The purchase of Carbonaceous Aerosol Speciation System (CASS) including TC08 (Real-Time Total Carbon Aerosol Analyzer, Model TCA-08,) and AE36 (Model AE36 Aethalometer®) is in the process at Faculty of Energy and Fuels. Receptor modelling PMF positive matrix factorization for identification of emission sources and source apportionment of PM is also performed at the Faculty of Physics and Applied Computer Science, AGH University of Kraków. Parameter eBC is measured by MABI (*Multi-Wavelength Absorption Black Carbon Instrument)* on collected PM on filters*.* Note that recently the KRK supersite staff obtained TNA in the frame of ATMO-ACCESS with *DEMOKRITOS, Athens, Greece for the determination of MAC for Kraków and Athens.*

Meteorological data is available on the webpage meteo.fis.agh.edu.pl. Selected datasets of other parameters are available in Carbon Portal (https://doi.org/10.18160/8DSK-R4JS).

The PL-KRK station is also working on the use of low-cost sensors. Several of them are used on drones.

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Table 6. *List of the measurements implemented at KRK supersite, parameters and time coverage (in black text) and measurements that are not implemented and that should be according to the NAQD in urban supersites (in red text). Shadowed in grey are the measurements related with Art 10 and Annex VII of the NAQD*

Component	Purpose	Device	Variables	Additional information
In situ aerosols measurements	Reply NAQD's requests	UFP- PNSD	UFP, PNSD 10-800 nm to switch to the RI-URBAN/ACTRIS standard	Recommended continuous
		Aethalometer AE36	BC concentration	Continuous since 2025 @ FEF
		TSI Optical Particle Sizer	Particle size distribution in 16 size channels (0.3-10µm)	Measurement campaigns Recommended continuous
		Met ONE BAM 1020	PM_{10}	Automatic since 2018
		3 SVEN LECKEL Low Volume / Medium Volume Samplers LVS / MVS (PM10, PM2.5, PM1 inlets)	PM_1 $PM_{2,5}$ PM_{10}	measurement campaigns since 2010 @ FPACS
		PM2.5 speciation	Elemental analysis, eBC analysis, gravimetrical analysis (also with microbalance resolution 0.001mg @ FPACS on request) Recommended to add sulphate, nitrate, chloride, ammonium	Recommended fix or discontinuous
		MABI	eBC analyses	On request @ FPACS
		XRF technique	Elements analysis	On request @ FPACS
		Carbonaceous Aerosol Speciation System (CASS)	EC, OC CAAS includes Real-Time Total Carbon Aerosol Analyzer (TCA-08) and Aethalometer (AE36)	On request @ FEF
		Hg analyser, MA-3000 (Nippon Instrument Corporation, Japan)	Hg speciation in aerosol	Measurement campaigns Need to be fix or discontinuous
		Organic and inorganic speciation	PAHs, OH-PAHs, NO_2-PAHs, brown carbon, ions, microplastics, levoglucosan Ions concentrations measurements using IC coupled with conductivity detector @ FEF (on request)	Measurement campaigns Need to be fix or discontinuous Using fractions filters from PM sampler
		Oxidative Potential	OP using LC-MS/MS, OP of PM using Ascorbic acid and glutathione tested (used on request @ FEF) Using DTT and AA assays	Need to be fix or discontinuous Using fractions filters from PM sampler
	Available for supporting interpretations	2 Stacked Units NILU	fine, coarse, TSP	
		Several LoCost PM sensors	PM_{10}, $PM_{2.5}$, PM_1 varies mobile sensors for mobile/drone/balloon measurements	Measurement campaigns
Gas		Thermo Model 43i	SO2	Automatic since 2018

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measurements	Reply NAQD's requests	Horiba APNA360	Nox	Automatic since 2018
		Horiba APMA360	CO	Automatic since 2018
		Thermo Model 49i	O3	Automatic since 2018
		NH_3 measurements, passive samplers	Recommended	Implement measurements with weekly or 10 days resolution
		VOCs with GC-MS	Recommended	Implement measurements
	GHGs Climate-Neutral	LICOR LI-7500DS for Eddy Covariance flux measurements	CO_2/H_2O @10Hz	Automatic since 2021
		Picarro G-2311-f	CO2, CH4 mixing ratios @1Hz or @10Hz	Automatic since 2021
		LICOR LI-7810 for mobile CH_4/CO_2 measurements	CO_2/CH_4	Measurement campaigns
Meteorology	Available for supporting interpretations	Vaisala WXT520 Meteorological integrates station	Temperature, Relative humidity, Pressure, Wind speed, Wind direction, Precipitation	Automatic since 2012
		Hukseflux NR-01 Net radiometer	Longwave (thermal) and shortvawe (Sun) radioation fluxes	Automatic since 2012
		LoCost meteo combo set for drones	Temperature, Relative humidity, Pressure, PM10	Measurement campaigns
		Mini sonic anemometer for drones	Wind speed, Wind direction, Sonic temperature	Measurement campaigns
Other		3 drone systems with max. payload up to 2.7 kg, flight time up to 50 min	Platforms for mobile 3D mapping of meteorology, PM_{10} or CO_2 CH_4 mixing ratios	Measurement campaigns
		Off-road car with mobile measurement system for CO2/CH4/PM 2D mapping installed	Car with standalone power system, positioning/wind speed datalogger and isokinetic inlet system for PM measurements	Measurement campaigns

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5. Additional information

5.1. Support from University of Silesia in Katowice

The University of Silesia in Katowice (US) hosts an excellent research facility referred to as the University Laboratories of Atmospheric Survey (ULAS) and the University Laboratories of Atmospheric Control (ULKA), located in Sosnowiec, 41-200, ul. Będzińska 60 (50° 17’ N, 19°08’E, 263 m a.s.l.).

US-ULAS, lead by Prof. Mariola Jabłońska (mariola.jablonska@us.edu.pl) is willing to support the proposed urban supersites by performing additional measurements using their mobile platform for in-situ aerosol studies and mobile platform for remote sensing studies.

US-ULKA has very well-equipped stationary laboratories for organic compound studies, the person in charge is Prof. Monika Fabiańska (monika.fabianska@us.edu.pl). The US-ULKA stationary laboratories perform following analyses: GC-MS of volatile organic compounds and heavier organic fraction of soluble air dust compounds, Py-GC-MS of black carbon, analyses of TOC, TC, TIC and TS.

Table 7. *Measurements performed by ULAS considered for supporting the proposed urban supersites done using two mobile platforms and analysed in their stational laboratories (ULKA) of University of Silesia.*

Air pollutants	***Averaging period***	***Measurement mode***
Benzene, CO, CO_2, SO_2, NO, NO_2, O_3, NH_3, HCl, HCN, Cl, formaldehyde, H_2S, total VOC	depends on measurement needs: 1s, 2s, 5s, 10s, or longer periods from several minutes to several hours	passive measurement
PM_1, $PM_{2.5}$, PM_{10}, TSP UFP, eBC	depends on measurement needs: 1s, 2s, 5s, 10s, or longer periods from several minutes to several hours	passive measurement
VOC GC-MS	depends on measurement	laboratory

Since several years US-ULAS specializes in mobile measurements, which are performed using an off-road vehicle and a manned hot-air balloon. The equipment used in mobile platforms is specially selected to measure in variable temperature and pressure conditions. In addition, during mobile measurements, atmospheric pollutant samples are collected for detailed phase and chemical analyses.

Detailed characterization of the collected atmospheric pollutants is carried out in the US-ULKA stationary laboratories and includes analyses using scanning electron microscopy, transmission electron microscopy, X-ray diffraction, X-ray fluorescence spectroscopy and GC-MS. The obtained results enable identification of sources emitting pollutants into the atmosphere and allow estimation of their quantity. This applies to both micro and nano particles.

US experts studying volatile organic compounds identify markers indicating their sources of origin. Detailed characteristics of air pollution allow for indicating their impact on human health, and allows for assessing their environmental threat.

Mobile measurements have great potential to support measurements at the stationary stations, this including the proposed urban supersites. They enable measurements to be taken in hard-to-reach places, and allow for measurements from unorganized sources, e.g. measurements of pollutant emissions were taken from self-igniting mining waste dumps (Fig. 9) located near large housing estates.

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Figure 9. *Measuring activities of US-ULAS and ULKA using different types of equipment form vehicle and hot-air balloon.*

5.2 Support with model analysis

WROCLAW

In Wrocław observations are supported by numerical modelling of atmospheric processes at the University of Wrocław using state-of-the-art meteorological and chemical transport models. The simulations are carried out both on a regional scale to cover the long-range distance transport of air masses and pollutants and on a local scale to provide high-resolution information for citizens.

The main meteorological tool is Weather Research and Forecasting Model (WRF), which is widely used by research and operational institutions for weather forecasting. Regional scale air quality is simulated with the complex chemical transport models Weather Research and Forecasting with Chemistry (WRF-Chem) and EMEP-MSC-W (EMEP4PL for the Polish application) and uEMEP, developed by Norwegian Meteorological Institute.

The ADMS-Urban Gaussian model is used for city scale air quality simulations. The models are used to provide air quality forecasts (https://airquality.uni.wroc.pl/forecasts) and to answer the questions related to air quality management (e.g the impact of different sources on air quality, the impact of local and non-local sources in air pollution concentrations).

The example of the city-scale modelling for Wrocław is presented in Fig. 10. This local-scale modelling **can be extended to the other locations** of the proposed urban supersites. The system is currently developed to provide concentrations of allergenic bioaerosols in the air.

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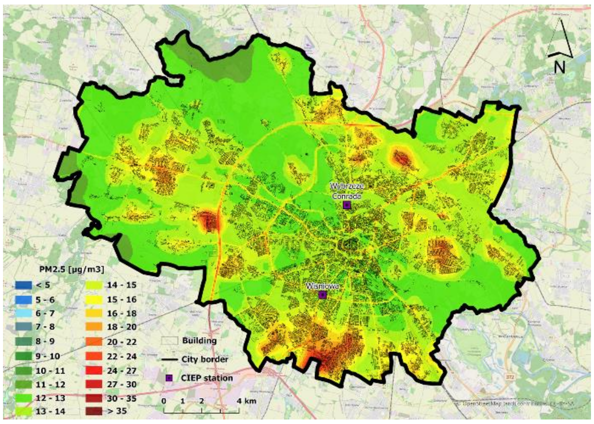
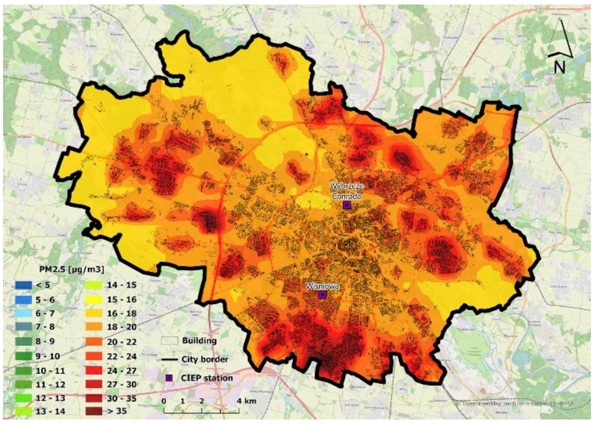
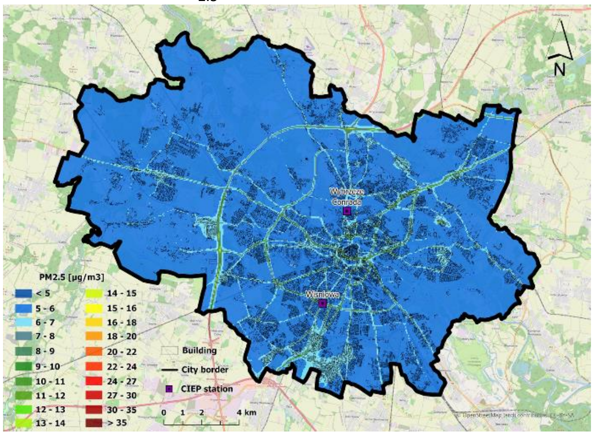


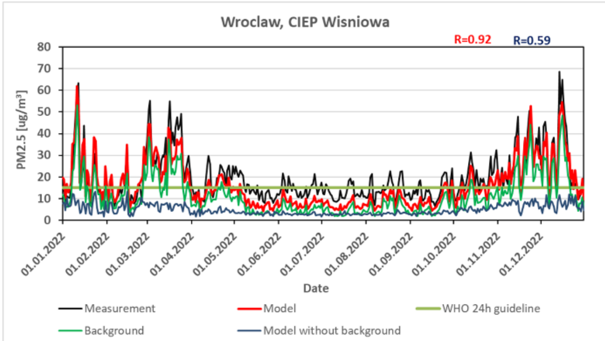
Annual mean $PM_{2.5}$ concentrations in Wrocław in 2022



Mean $PM_{2.5}$ concentrations in Wrocław in winter 2022



Mean $PM_{2.5}$ concentrations in Wrocław in summer 2022



Daily $PM_{2.5}$ concentrations in 2022 at CIEP Wisniowa (traffic) stations. Pearson's correlation index R: 1) in red color is for ADMS-Urban with background concentrations; 2) in dark blue is for ADMS-Urban without background concentrations.

Figure 10. *The examples of modelling of $PM_{2.5}$ concentartion involving ADMS-Urban, EMEP4PL model, source: Porwisiak P, Werner M., Kryza M., ApSimon H., Woodward H., Mehlig D., Gawuc L., Szymankiewicz K., Sawiński T. 2024. Application of ADMS-Urban for an area with a high contribution of residential heating emissions - model verification and sensitivity study for $PM_{2.5}$, Science of The Total Environment, V. 907, 168011, https://doi.org/10.1016/j.scitotenv.2023.168011.*

WARSAW

In Warsaw, observations are also supported with numerical modelling of atmospheric processes done at the University of Warsaw using state-of-the-art models well recognized by research institutions. The simulations are carried out on an urban scale to assess pollutants transport at fine scale to provide high-resolution information for scientific research purpose. The main asset is Parallel Large Eddy Simulation Model (PALM) optimized for Warsaw urban domain used to assess how turbulence and convection behave across different days/seasons in the city. The model has a chemical module able to simulate the pollution at urban scale. The example of the city-scale PALM modelling for Warsaw is presented in Fig. 11. Additionally, another computational fluid dynamics (CFD) modelling of aerosol transport over complex urban areas in the superfine local-scale is done using Code_Saturne that solves the Navier-Stokes equations with scalar transport for 2D, 2D-axisymmetric, and 3D flows. Another model used for urban modelling is Eulerian/semi-Lagrangian fluid solver (EULAG) for simulating thermo-fluid flows across a wide range of scales and physical scenarios. Such local-scale PALM modelling **can be set up also for other proposed urban supersites**.

At University of Warsaw a wide range of tools highly valued in research community is used on everyday basis, this includes transport models such as HySPLIT, NMMB/BSC-Dust model, as well as aerosol prediction models NAAPS, FLEXPART. For data visualization we use in-house developed tools (LIRAMI, LILI, EMERALD, ProFiler, ProDuctor), as

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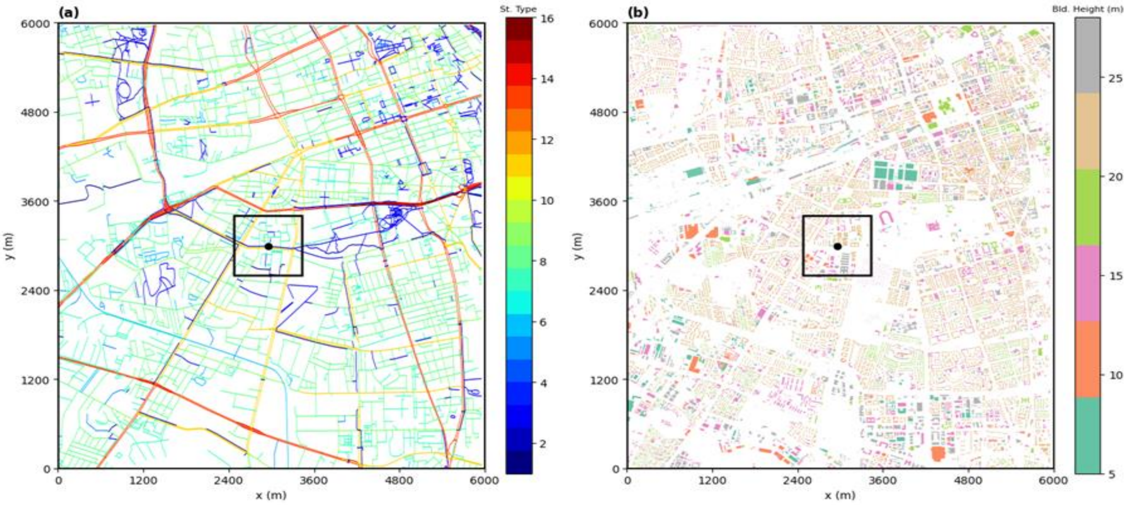
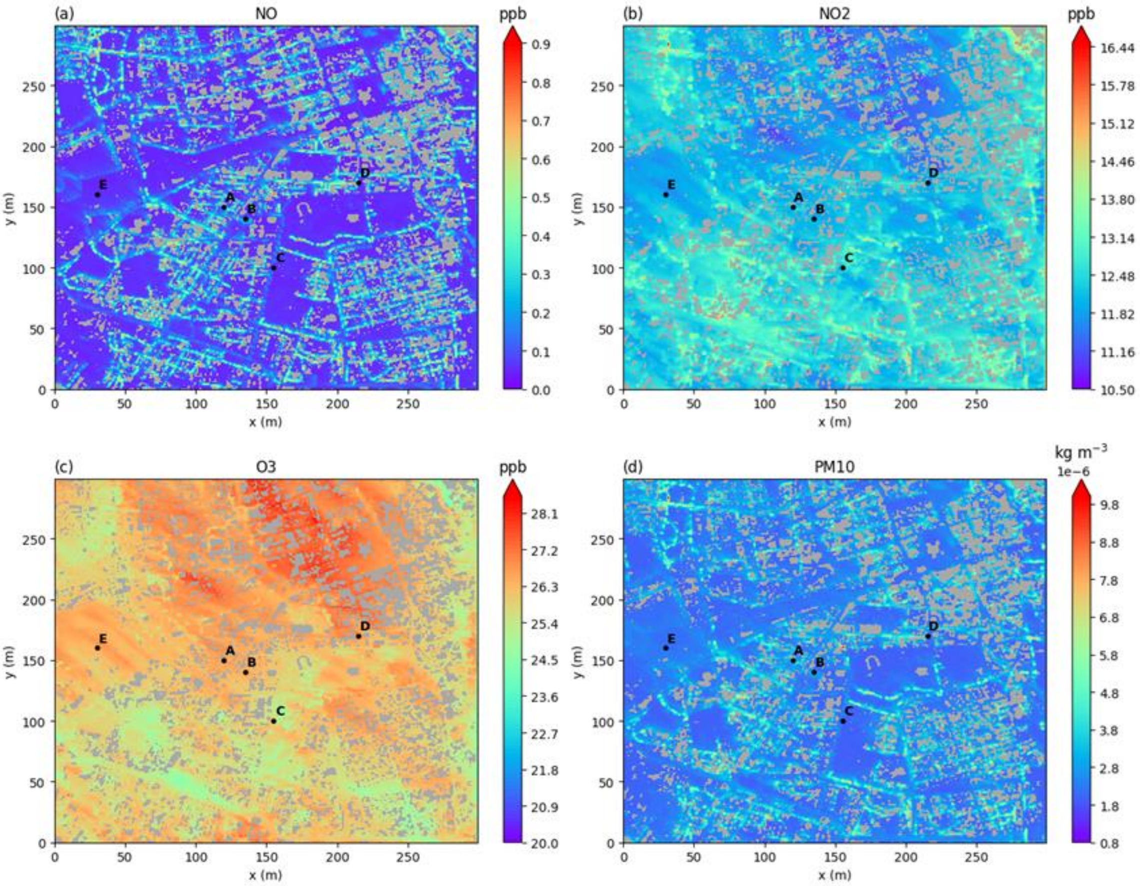
well as community tools (ZEFIR, ATLAS, SCC, GRASP). An example of such tools is depicted in Fig. 12. The knowledge of these tools can be shared with other urban supersites to increase the interpretational expertize.



Domain of 6 x 6 km centered at the proposed urban supersite in Warsaw with a) streat type and b) building height



Distribution of pollutants in above defined domain computed with PALM

Figure 11. *Examples of modelling of NO, NO2, O3, and $PM_{2.5}$ concentartion using PALM for defined domain computed for vicinity of proposed urban supersite(center of plots) in Warsaw , source: Rayonil Carneiro, University of Warsaw.*

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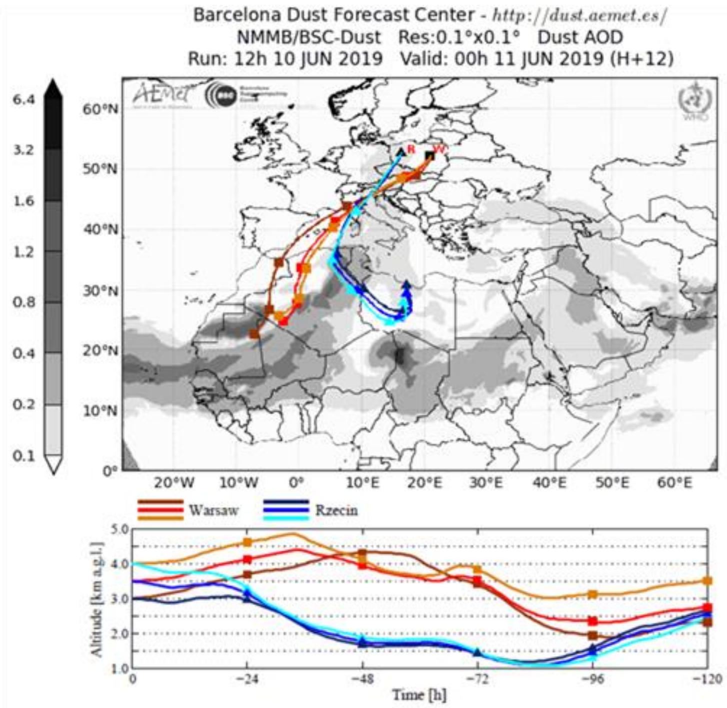

Figure 12. *Air-mass trajectories (blue/red) superimposed over mineral dust prediction (gray) during the Saharan dust inflow to Poland, source: Szczepanik D.M., Poczta P., Talianu C., Böckmann C., Ritter C., Stefanie H., Toanca F., Chojnicki B.H., Schüttemeyer D., Stachlewska I.S., 2023, Spatio-temporal evolution of long-range transported mineral desert dust properties over rural and urban sites in Central Europe, Science of The Total Environment, vol. 903, art. 166173, 10.1016/j.scitotenv.2023.166173*

KRAKOW

In Kraków source identification and apportionment are performed by receptor modelling Positive Matrix Factorization (PMF). The input for modelling are elements, ions, OC, EC, BC concentrations at ambient air. An example of PMF is given in Figure 13.

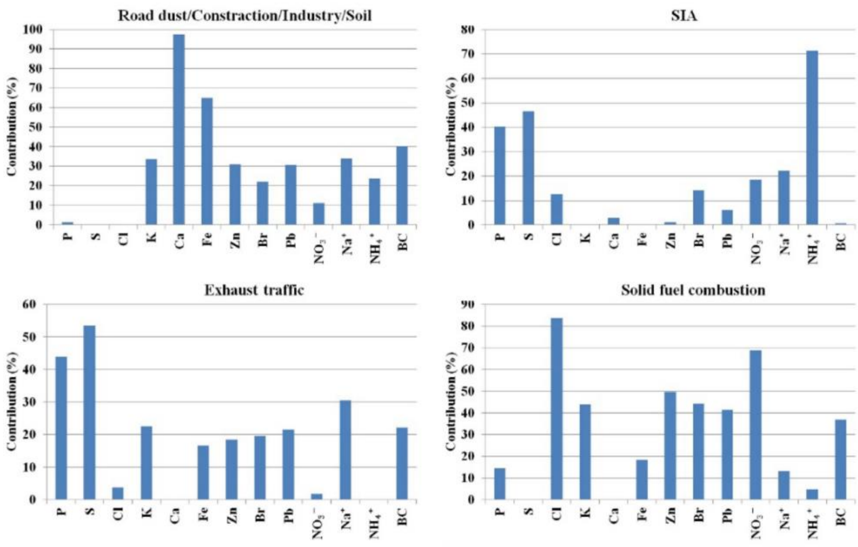

Figure 13. *Concentration of chemical species and emission sources PM2.5 for PMF Factor profiles for 2020/2021, source: Rys A., Samek L., Stegowski Z., Styszko K., 2022. Comparison of concentrations of chemical species and emission sources PM2.5 before pandemic and during pandemic in Kraków, Poland, Scientifc Reports 12:16481 | https://doi.org/10.1038/s41598-022-21012-x.*

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6. Recommendations and approaches to promote the upscaling of the STs at the Polish urban supersites

6.1. Recommendations for Polish stakeholders

On 22/09/2011, the World Health Organization (WHO) issued the WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulphur dioxide and carbon monoxide, which did not give guidelines values for protection population against exposure to UFP, BC, PM components, and other advanced AQ parameters, but recommended measuring these in a harmonised way to have solid datasets for further epidemiological studies.

On 26/10/2022 DG ENV from the EC issued a proposal for a new AQD., and on the 08/03/2024 a final proposal was agreed between the Council of Europe and the European Parliament. It was submitted for approval to the two institutions. This proposal for a NAQD in Europe, following recommendations from the 2021 WHO AQ Guidelines, requires in Art10 to build up a network of supersites for measuring advanced AQ parameters, such as UFP, PNSD, BC, PM speciation, OP, and NH3. Furthermore, a list of VOCs to be measured is included also in Annex VII. The new Air Quality Directive (2024/2881/EC) was published on 20 November 2024 and currently EU countries undergo the legalization and implementation process.

This document summarises the proposal for upscaling urban air quality (AQ) supersites in Poland to fulfil the requirements of the proposal for a new EU AQ Directive (NAQD) based on guidance of RI-URBANS/ACTRIS. There are other parameters in the Art10 of the NAQD that are not included in this report.

On the other hand, the EU launched the Mission of Climate Neutral and Smart Cities. There are currently, 112 climate-neutral smart cities that are willing to be labelled as a such before 2030. Out of the proposed in our document supersites 3 of them **Kraków, Warsaw, and Wrocław** are included in the aforementioned list of cities. As 31st December 2024, 43 cities have received the label are: Leuven (Belgium), Limassol (Cyprus), Espoo, Lahti, Lappeenranta, Tampere, Turku (Finland), Marseille, Lyon (France), Aachen, Heidelberg, Münster (Germany), Ioannina, Kalamata, Kozani, Thessaloniki, Trikala (Greece), Miskolc, Pecs (Hungary), Eilat (Israel), Bologna, Bergamo, Florence, Milan,Parma, Prato, Turin (Italy), Liepāja (Latvia), Guimaraes, Lisbon, Porto (Portugal), Bucharest 2nd District, Suceava (Romania), Barcelona, Seville (Spain), Ljubljana, Kranj (Slovenia), Gothenburg, Gävle, Malmö, Umeå (Sweden), The Hague (the Netherlands), and Izmir (Türkiye). None form Poland so far.

There are continuous calls to which the Polish cities might apply, and once there receive the label the have exclusive funding opportunities to implement actions. We are aware that cities like Zabrze and Racibórz are not likely to be expected to apply for such label due to their specific locations, orography and challenging air-quality situation. Still this may not be excluded.

To receive information on the calls for labelling and possible financial support we recommend contacting:

"YEROYANNI Marie" Marie.Yeroyanni@ec.europa.eu

"OLEJNIK Aleksandra" Aleksandra.OLEJNIK@ec.europa.eu

It would be very convenient to install AQ and GHGs advanced measurements in urban supersites. Thus applying for financial support once the cities are labelled as Climate-Neutral and Smart cities by the EC will help to implement these measurements in Poland because these cities are among the 112 cities envisaged by the EC.

After the analyses of RI-URBANS-ACTRIS-ICOS members, together with Polish experts from the involved Universities and research performing organizations, we suggest starting the upscaling of the STs referred above, using the

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existing research infrastructures listed in each of the 4 supersites (Warsaw, Wrocław, Kraków, and Zabrze) and complementing these with the instrumentation marked in red in the specific tables presented in prior chapters.

For this, financial support from the Polish Administrations will be required, both for purchasing the complementing instruments and for running measurements, laboratory work, and maintenance, as well as for reports' writing. The rough budget estimation to this end are summarised Table 8.

Table 8. *Budget estimations for upscalling the STs proposed in prior tables for the measurement of advanced AQ parameters in urban supersites from Poland.*

a) Estimated costs of station development and retrofitting (October 2024)

Supersite location	**Recommended purchase of instrumentation**	**Investment Cost (Euro) per instrument & total**
Warsaw	SMPS 3938W50-CEN VOCs with GC-MS NH3 passive samplers	150 000.00 70 000.00 3 000.00 Total: 223 000.00 Euro
Wrocław	EC ToT analyses for PM speciation VOCs with GC-MS NH3 passive samplers	65 000.00 70 000.00 3 000.00 Total: 138 000.00 Euro
Zabrze	SMPS 3938W50-CEN VOCs with GC-MS	150 000.00 70 000.00 Total: 220 000.00 Euro
Kraków	SMPS 3938W50-CEN VOCs with GC-MS NH3 passive samplers	150 000.00 70 000.00 3 000.00 Total: 223 000.00 Euro 0
TOTAL INVESTMENT NEEDED		**804 000.00 Euro**

b) Costs associated with chemical analysis of PM conducted offline in a chemical laboratory,the price per sample according to cost in October 2024.

Analysis	**Cost per sample (Euro)**
Anions (Cl, NO2, NO3, Br, PO43-, SO42-)	2.50
Cation (Li+, K+, Na+, NH4+, Ca2+, Mg2+)	2.50
Metals (As, Cd, Co, Cr, Cu, Mn, Ni, Pb, Sb, Tl, V)	15.00
Elements by XRF (Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Rb, Sr, As, Pb)	10.00
Sampling and gravimetrical analysis	LV 5.00 HV 10.00
OC/EC	5.00
Sugars markers	12.00

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Concerns for the costs of samples analysis:

There two types of costs. Actual cost of the laboratory (AC) just accounting for the consumables and Real Cost of the laboratory (RC) taking into account technician salary and instruments depreciation. Note that prices that a central laboratory can ask is about factor of 2-3 times higher compared to Real Cost (RC).

The total cost is including the cost of appropriate water quality, standards, reagents, Eppendorfs, autosampler vessels, etc., as well as periodic replacement of columns and suppressors, and equipment maintenance.

Below are given estimations for both AC and RC.

1) **Anion and cations.** One need to consider that after 2000 samples a new pre and post column (3 000 Euro) and new suppressor (2 500 Euro) will be needed. If one add chemicals, standards, and gases (He) without any depreciation cost for the instrument and without salary of a technician, the estimated actual cost (AC) is about 4 000 Euro for each analysis of anions and cations. Real cost (RC) is almost a factor of 2-3 higher to account for technician salary and instruments depreciation.
2) **Trace metals (ICP-MS):** The most expensive is liquid Argon with price of a tank of the order of 3 000 Euro for 1000 analysis (non-stop operation). One should add acids for digestion. One need to add consumables for the instrument (cones, torches etc, which should be changed after 5000 samples with price of 5 000 Euro) with other consumables, then AC is about 15 Euro per sample. RC is almost a factor of 3 higher to account for technician salary and instruments depreciation.
3) **Elements by XRF**: The most important is instrument depreciation. The estimates are roughly the same (if not smaller) compared to ICP-MS, i.e. 10 Euro and 30 Euro per sample for AC and RC, respectively.
4) **Sampling and gravimetric analysis**. The main cost is filter price which for low volume (LV) is roughly 5 Euro and high volume (HV) 10 Euro for each sample, which are the actual costs. If one add technician salary and samplers' depreciation, then RC are factor of 2 higher, i.e. 10 Euro for LV and 20 Euro for HV.
5) **OC/EC analysis**. The main cost are gases (3 000 Euro) and oven to be changed after 2000-3000 samples, depending on the nature of samples (about 3 000 Euro), which gives roughly 5 Euro per sample as AC. Then, RC is almost a factor of 2 higher to account for technician salary and instrument depreciation.
6) **Sugars as biomass burning tracers**. Column should be changed more often compared to IC, as well as electrodes (every 1000 samples) with price almost 10 000 Euro for both. By adding chemicals and standards, then AC is about 12 Euros per sample. RC is almost a factor of 2-3 higher to account for technician salary and instruments depreciation.

Additional comments:

- Due to the lack of recommended measurement techniques for oxidative potential analysis, it is likely that for online measurements, we should utilize MARGA (the cost not included in Table).
- The online, continuous chemical compositions and mass loadings of non-refractory PM: organic, sulfate, nitrate, ammonium, and chloride (ACSM) – cost ca. 470.000 Euro
- The VAT is included in the cost estimates.
- The operational costs are not included in the budget.

It is also important than in some of the supersites, measurements of greenhouse pollutants are also measured and this is very important for including in the same urban supersite pollutants relevant for AQ and climate change.

If all these supersites are implemented with the indicated measurements the following requirements of the forthcoming NAQD for supersites might be covered (those shadowed in green):

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Pollutant	***Type of measurements***
PM_{10}, $PM_{2.5}$, UFP, BC	Fixed measurements
NO_2, O_3	Fixed measurements
SO_2, CO	Fixed or indicative measurements
Size distribution of UFP	Fixed or indicative measurements
Benzo(a)pyrene, other polycyclic aromatic hydrocarbons (PAH) as relevant	Fixed or indicative measurements
Total deposition of benzo(a)pyrene, and other polycyclic aromatic hydrocarbons (PAH) as relevant	Fixed or indicative measurements
Arsenic, cadmium, lead, and nickel	Fixed or indicative measurements
Total deposition of arsenic, cadmium, lead, nickel and mercury	Fixed or indicative measurements
Benzene	Fixed or indicative measurements
Chemical composition of $PM_{2.5}$ in accordance with Section 1 of Annex VII	Fixed or indicative measurements

NH_3 (recommended, not requested for urban background
Oxidative potencial (recommended)

VOCs (48 VOCs species recommended)

Measurement of $PM_{2,5}$ must include at least the total mass concentration and concentrations of appropariate compounds to characterise its chemical composition. At least the list of chemical species given below shall be included.

SO_4^{2-}	Na^+	NH_4^-	Ca^{2+}	elemental carbon (EC)
NO_3^-	K^+	Cl^-	Mg^{2+}	organic carbon (OC)

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6.2. Operational recommendations

It is highly recommended that the supersites will supply the AQMNs reports and datasets with the format required by the Administrations, as well as an annual scientific report highlighting the main AQ findings that can be of interest for AQ managers.

Furthermore, we recommend building up a scientific/technical structure in which specific teams with experience guide the implementation of the advanced AQ parameters in all the Polish supersites. Thus, if a group has experience and is already measuring UFP and PNSD in their supersite, they should guide the purchase of instruments, implementation and maintenances in the other supersites. Accordingly, we recommend the following structure (that will support harmonisation of measurements in the country):

- **UFP-PNSD:** Anetta Drzeniecka-Osiadacz University of Wrocław
- **BC and eBC:** Iwona Stachlewska University of Warsaw; Lucyna Samek AGH University of Kraków
- **$PM_{2.5}$ speciation for OC, EC, metals, ions:** Katarzyna Jaworek Institute of Environmental Engineering of the Polish Academy of Sciences; Katarzyna Styszko (OC, EC, anions) AGH University of Kraków; Lucyna Samek (elements by XRF) AGH University of Kraków
- **$PM_{2.5}$ speciation for organic compounds:** Katarzyna Jaworek Institute of Environmental Engineering of the Polish Academy of Sciences (standard approach: biomass burning markers, WWA, BETX); Katarzyna Styszko (PAHs, derivatives of PAHs, sugars markers) AGH University of Kraków
- **VOCs:** Monika Fabiańska University of Silesia
- **Oxidative Potential:** Katarzyna Styszko AGH University of Kraków;
- **NH_3 with passive samplers:** Katarzyna Jaworek Institute of Environmental Engineering of the Polish Academy of Sciences
- **GHGs:** Miroslaw Zimnoch AGH University of Kraków, Maciej Górka University of Wrocław

Relevance of additional information provided in some supersites

The AQ information at the surface is often not sufficient to draw more generalized conclusion on the air quality, especially in terms of the long-range transport over the measurement site/area. For the ability of AQ numerical models to forecast the air pollution episodes, knowledge of the vertical structure of the atmosphere is essential information that need to be included in AQ monitoring. An important parameter is the height of the mixed layer, in which the air pollution emitted from sources on the ground are mixed. The height of the mixed layer has a significant effect on the concentrations of air pollution. Correctly generating the height of the mixing layer is difficult in numerical models, especially in complex environments like urban canopies. Therefore, monitoring the height of the mixing layer inside and around cities using aerosol lidars or ceilometers that are able to detect the presence of aerosols up to, at least, several kilometres height in crucial. In addition, wind lidars that can measure vertical profiles of wind will enable numerical models to better forecast air pollution once assimilated. Height of the mixed layer is provided as ACTRIS variable: planetary boundary height form lidars and ceilometers. The boundary layer height lidar measurements are performed at the two of the proposed urban supersites in Warsaw (with Mie-Raman lidar continuous since 2015 data automatic provision to EARLINET-ACTRIS, with wind-turbulence Doppler lidar since 2021 data automatic provision to CLOUDNET-ACTRIS) and Wrocław (with Mie-Raman lidar since 2024). This sites could be used for proper estimation of the long-range transported aerosol/pollution to the sites (e.g. Stachlewska et al. 2017, 2018, Szczepanik et al 2023, Janicka et al 2023). Such instrumental configuration is also of extreme importance for synergic evaluation of insitu and remote sensing data towards comping methodologies for calculating the reduction amount in case of non-anthropogenic air-quality limit levels exidances.

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Although the recommendations for the vertical observations are mainly from RI-URBANS and ACTRIS, the similar argumentation can be extrapolated to GHG (ICOS). There is a scientific and service driven incentive to co-locate observations of greenhouse gas concentrations and fluxes with ICOS and air quality with RI-URBANS and ACTRIS, when possible. This would allow e.g. simultaneous quantification of anthropogenic emissions of CO2 and air pollutants and developing optimized tools for emission reductions contributing to climate and air quality targets. There is currently discussion within ICOS on the need to better characterise the fluxes of the GHG with use of the profiling. For these new technologies have been proposed jointly by ACTRIS and ICOS, what resulted in preparation of joint proposal for EC funding on developments and optimization of new tools (automated drone observations, lidar techniques, etc.). The information on planetary boundary layer height is therefore important also for ICOS. Currently one of the proposed urban supersites Kraków is included in the Polish plans for joining the ICOS-ERIC in the future. Moreover, also Warsaw urban supersite took a grassroots initiatives to obtain funding for purchase and implementation of the GHG monitoring instrumentation, according to ICOS-ERIC (proposal under evaluation).

Reference to papers:

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6.3. Recommendations for other regions based on the Polish experience

The Polish experience evidenced a number of key issues to be considered when addressing potential upscaling activities in other EU regions:

- Value of existing infrastructures: because upscaling may require significant investment, it is essential to build on the value of existing infrastructures. Currently operational stations, or networks of stations, should be used as the basis for upscaling activities.
- Complementary pollutants observations: It is also important than in some of the supersites, measurements of greenhouse pollutants are also measured and this is very important for including in the same urban supersite pollutants relevant for AQ and climate change.
- Collaborative research: across disciplines (e.g., surface *vs*. vertical measurements) as well as across institutions (e.g., AQ monitoring networks and research institutions) is central to the success of upscaling activities.
- Collaboration on equal terms: similarly, collaboration may only be effective when discussions between AQ monitoring networks, researchers and Administrations are developed at equal level.
- Awareness: baseline awareness levels outside the research community are frequently low. Initial discussions describing the roles of infrastructures, RI-URBANS, ACTRIS, etc. constitute a necessary starting point when engaging with stakeholders. Similarly, the recent trends in terms of these platforms and their role with regard to the AQ Directive are necessary.
- Involvement of Administration at different levels: all levels of Administration (local, regional, national) should be involved in discussions from the early stages.
- Proactivity: facilitating the active engagement of Administrations and AQ networks in discussions regarding EU regulations (e.g., AQ Directive) contributes to the visibility of the benefits of upscaling activities, and therefore contribute to them.
- Portfolio of STs available: SOPs, calibrations, modelling etc., are topics of interest for the networks, which are useful for communication of the benefits of upscaling, as opposed to focusing on instrumentation and economic investments needed, only.
- Choice of supersites: We fulle reckognize that in the cases of Poland our document provides only recommendations and the final decision for the choice of supersites is in hands of the Polish Chief Inspectorate of the Environmental Protection (CIEP). This will be very linkely a situation also in other EU countries, respectively to their AQMN.
- Cooperation AQMN with ACTRIS-ERIC: We strongly recommend that it would be highly beneficial if CIEP / AQMN cooperated with ACTRIS-Poland / ACTRIS-ERIC sites, to ensure that ACTRIS expertize can be offered regarding the data provision and instrument operation to AQMN. At the same time we recommend that at least one site per country shall be built/operated directly by AQMN.

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