Deliverable D26 (D4.5)

Nanoparticle aerosol pilots, sustainability, associated benefits for AQMNs and AQ policy

RI-URBANS

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

By

UoB, UHEL, CSIC & EMPA

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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 D26 (D4.5): Nanoparticle aerosol pilots, sustainability, associated benefits for AQMNs and AQ policy

Authors: David Beddows (UoB), Katrianne Lehtipalo (UHEL), Cristina Reche (CSIC), Noemi Perez (CSIC), Christoph Hueglin (EMPA) & Roy Harrison (UoB)

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Comments	This document summarises the main results obtained in the pilot 2 of WP4 were ultrafine (UFP)-particle number size distribution (PNSD) measurements were carried out using the recommendations of Service Tool (ST1) on UFP-PNSD measurements.

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1. About this document

WP4 deals with the development of pilot measurements and studies of Service Tools (STs) provided by WP1, WP2 and WP3. There are 4 pilot studies into WP4 and one of them deals with the measurements of ultrafine (UFP)-particle number size distribution (PNSD) measurements in a harmonised way.

This document addresses the deliverable D26 (D4.5): Summary of the nanoparticle aerosol pilots, sustainability, associated benefits for air quality (AQ) monitoring networks (AQMNs) and AQ policy (UOB, R/PU, M40), and summarises the main results obtained in the pilot 2 of WP4 were UFP-PNSD measurements were carried out using the recommendations of ST1 on UFP-PNSD measurements. The pilot also demonstrated the near-real-time (NRT) open information of these measurements, whose data are sent in a NRT way to EBAS (ACTRIS Data Center).

This is a public document that will be distributed to all RI-URBANS partners for their use and submitted to the European Commission as a RI-URBANS deliverable D26 (D4.5). This document can be downloaded at https://riurbans.eu/work-package-4/#deliverables-wp4.

2. Summary of the nano particle aerosol pilots, level 1

Within RI-Urbans WP4 (Task 4.2) this Pilot Study provided near-real time particle number size distribution data from different city environments in Europe. NRT (near-real-time) aerosol number size distributions in the three core pilot sites (Palau Reial - Barcelona, Kumpula Helsinki and BAQS – Birmingham, Table 1) were collected accorded to ACTRIS protocols for up to and over one year. Particle number size distributions were also measured at Mäkelänkatu in Helsinki and in a fourth city Kaserne, Zurich, although NRT data transmission has not yet been completed.

***Table 1**. Three core pilot sites considered.*

Station	Site	Lat/Long	Core Pilot Site ✓ / ×
Palau Reial, Spain	ES0019U	41.39/2.12	✓ Barcelona
Kumpula (SMEAR III), Finland	FI0038U	60.20/24.96	✓ Helsinki
Mäkelänkatu, Finland	FI0039U	60.20/24.95	× Helsinki
BAQS , United Kingdom	GB0101U	52.46/-1.93	✓ Birmingham
Kaserne, Switzerland	CH0010U	47.37/8.53	× Zurich

2.1 Barcelona

2.1.1 Site description: Palau Reial

Barcelona supersite (BCN) is reference for AQ management authorities and AQ research in Spain. The site is operated in collaboration with the Catalan Government (GENCAT). It should also be highlighted that BCN is a pilot in ACTRIS –CAMS system software, designed to report data in NRT.

Barcelona has 1.6 million inhabitants (3.6 million in its metropolitan area) and is located in a coastal area in the western Mediterranean (Figure 2.1.1.). It is a densely populated area, also characterized by a high density of motor vehicles and by a compact architecture hampering dispersion of pollutants. The Barcelona Ring Roads Low Emission Zone (LEZ) was implemented in January 2020, so that the pilot will supply fundamental information for the evaluation of this plan.

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Air quality in Barcelona (Figure 2.1.1) is influenced by industrial emissions from nearby areas. Additionally, the city hosts Barcelona harbour, one of the largest in the Mediterranean, and the second-largest airport in Spain, located just 10 km from the city center. NO_2 levels in Barcelona frequently exceed EU regulatory limits, and concentrations of PM10, PM2.5, and NO_2 are often above the WHO guidelines. The average pollutant concentrations measured at the Barcelona site are within the typical range for urban environments in southern Europe: O_3 70 µg/m³; NO 2.5 µg/m³; NO_2 18 µg/m³; SO_2 2.1 µg/m³; BC 925 ng/m³; $PM_{2.5}$ 17 µg/m³; PM_{10} 23 µg/m³; N 11,000 particles/cm³. However, the persistent exceedances of WHO limits highlight the ongoing air quality challenges in the city.

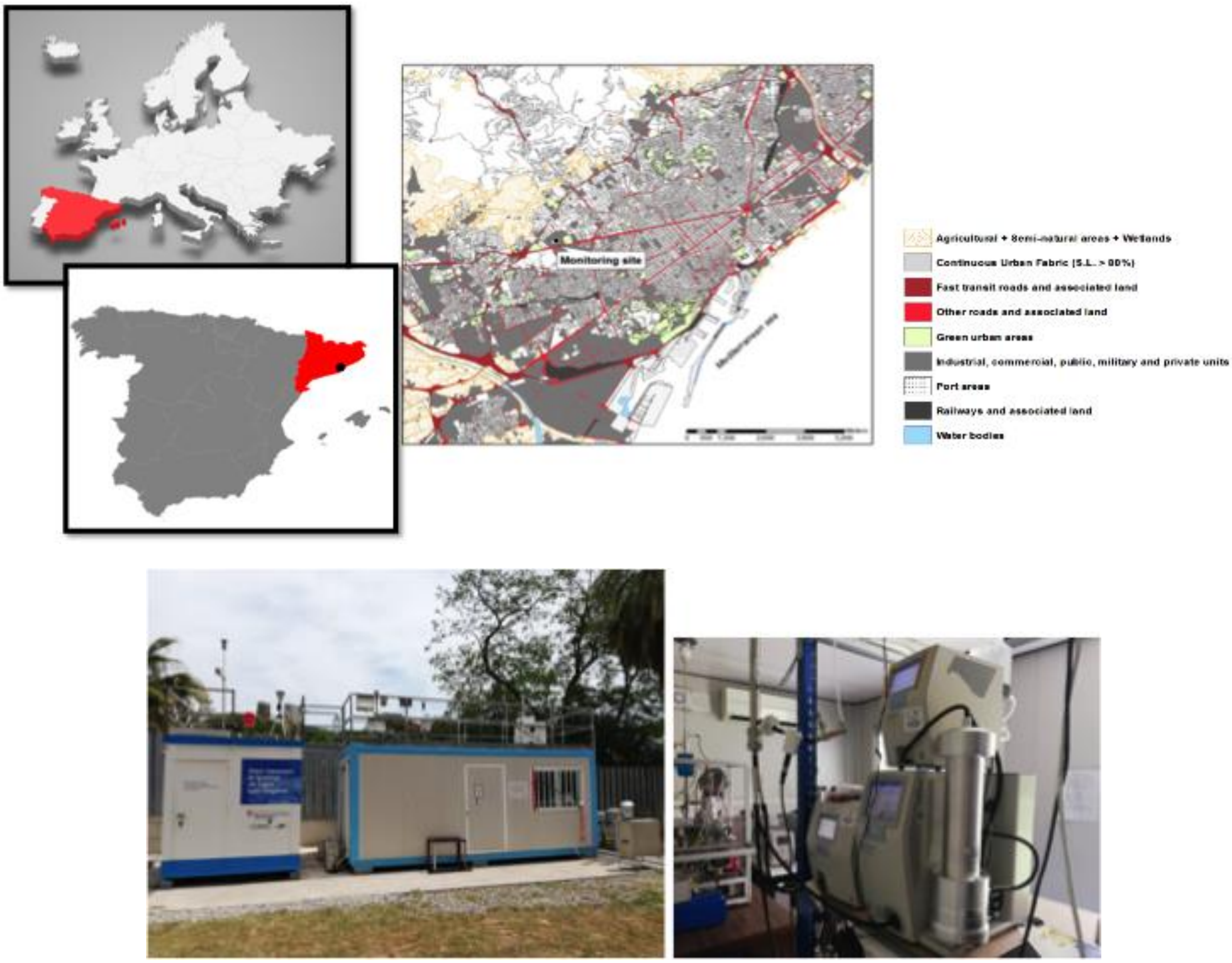

Figure 2.1.1. *Barcelona monitoring station (BCN, urban background). Upper panel: Overview of the positioning of Barcelona and land use of the area. Lower panel: monitoring site and instrumentation for UFP measurements.*

2.1.2. Instrumentation & data

The ACTRIS compliant MPSS system comprised of a TSI3938 SMPS made up of a TSI 3082 classifier (with positive voltage capabilities), a wide range DMA TSI 3083 (10-800 nm) and a TSI 3750 CPC (DP_{50} = 10 nm). The MPSS samples from a BGI $PM_{2.5}$ inlet, exclusively dedicated to UFP measurements. The aerosol is dried before the splitter using a TROPOS Nafion dryer operated with a compressor and a membrane dryer, which dries aerosol to RH<40%. The latest TSI AIM11 (monitoring version) software is used in addition to a continual export of data to the CAMS system.

A short sample of NRT size distributions measured in the BCN station during the year trial of NRT as seen on the *https://ebas-nrt.nilu.no/* website can be found in Figure 2.1.2.

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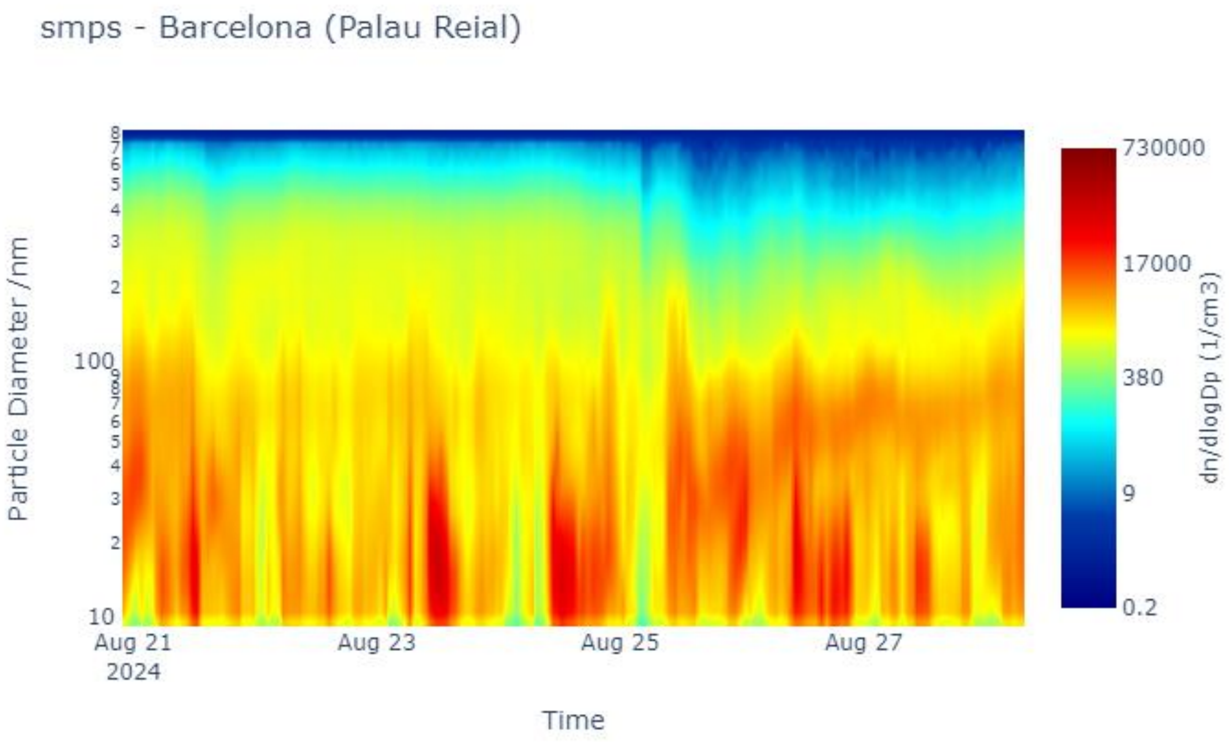

***Figure 2.1.2**. A short sample of NRT size distributions measured in the BCN station during the year trial of NRT as seen on the https://ebas-nrt.nilu.no/ website.*

2.2. Birmingham

2.2.1 Site description: BAQS Birmingham Air Quality Site

With a population of 1.14 million in 2019 (ONS, 2017), the UK city of Birmingham is the location (LAT = 52° 27' 19.872'' N and LONG = 1° 55' 44.213'' W, (Figure 2.2.1) of Birmingham Air Quality Site (BAQS; urban background). The Birmingham facility (Figure 2.2.1) is located within a self-contained cabin within a small green space within the grounds of the University which itself is surrounded by green space residential and campus facilities. There is a trainline 84 m NW of the site and the nearest roads are: Farquhar Rd (177 m); Edgbaston Park Road (132 m); and Pritchatts Road (262 m). The next largest facility is the Queen Elizabeth Hospital (1.1 km) and the edge of the city centre (taken as the A4540 ring-road) is 2.1 km to the NE. According to the West Midlands Road traffic statistics, 4.21 billion vehicle miles were travelled on roads in Birmingham in 2019, 3.44 billion of which were cars and taxis. Edgbaston Park Road takes roughly 4,800 vehicle per day and Vincents Drive takes traffic from Pritchatts Road and Farquhar Road to the Hospital takes roughly 6,814 vehicle per day (DfT Road Traffic Statistics for counting sites 945338 and 947763: https://roadtraffic.dft.gov.uk/local-authorities/141). The site experiences an average temperature of 11 ± 5 ^{o}C.

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Figure 2.2.1. *BAQS Birmingham Air Quality Supersite (urban background) in Birmingham, UK. Upper panel: Overview of the positioning of the site. Lower left panel: location of BAQS within the University grounds. Lower right panel: Photograph of the upgraded MPSS and CEN system to ACTRIS standards, now scanning from 10-800 nm.*

2.2.2. Instrumentation & data

Since the start of its operation in 2019, BAQS has measured typical yearly mean values for gases and aerosol of: O_3 48 $\mu g/m^3$; NO 3 $\mu g/m^3$; NO_2 18 $\mu g/m^3$; BC 777 ng/m^3; $PM_{2.5}$ 9.4 $\mu g/m^3$; PM_{10} 13 $\mu g/m^3$, and for particle number measurements the site has recently gone through an upgrade to ACTRIS standards.

Figure 2.2.1 shows the ACTRIS-compliant Dual Polarity TSI-3082 classifier fitted with a DMA3083 which measures the particle size range from 10 nm to 800 nm in one single scan. The MPSS samples off a 4-way flow splitter from a TSI-3750200 atmospheric sampling $PM_{2.5}$ inlet designed to requirements specified in the European standards CEN/TS 16976 and 17434. Aerosol is dried to <40% relative humidity. As with the Barcelona site, TSI AIMS 11 (monitoring) software is essential for the ability to export text data to the NRT.

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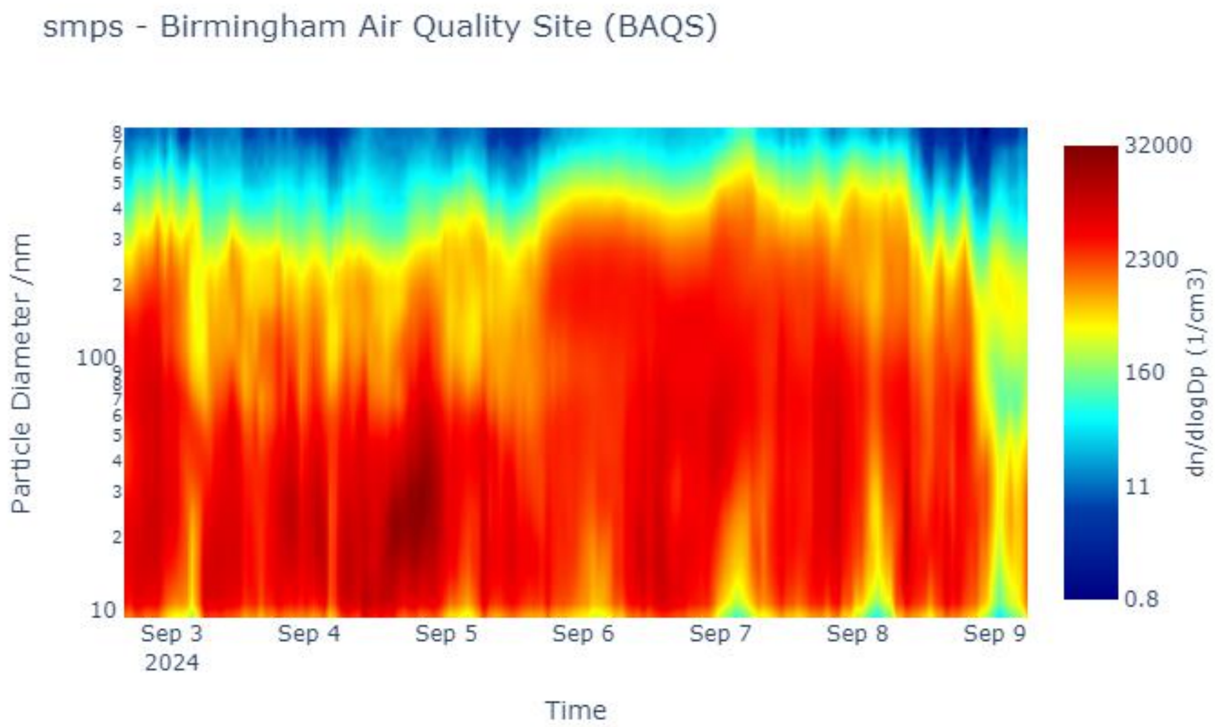

Figure 2.2.2. *A short sample of NRT size distributions measured in the BAQS station during the year trial of NRT as seen on the https://ebas-nrt.nilu.no/ website.*

2.3 Helsinki

2.3.1 Site description: Mäkelänkatu and Kumpula (SMEAR III)

Helsinki is the capital of Finland, located on the coast of the Baltic Sea (LAT = 60° 10' 15'' N; LONG = 24° 56' 15'' E). The population is 660 000 inhabitants, with ca. 1.6M people living in the metropolitan area surrounding Helsinki. In Helsinki, particle number size distribution measurements within RI-URBANS are conducted at two nearby sites. Both are located ca. 4 km from Helsinki city center (see Figure 2.3.1). Mäkelänkatu site is an urban traffic site operated by the Helsinki Regional Air Quality Authority (HSY), while SMEAR III is an urban background site operated jointly by University of Helsinki and Finnish Meteorological Institute (Figure 2.3.1).

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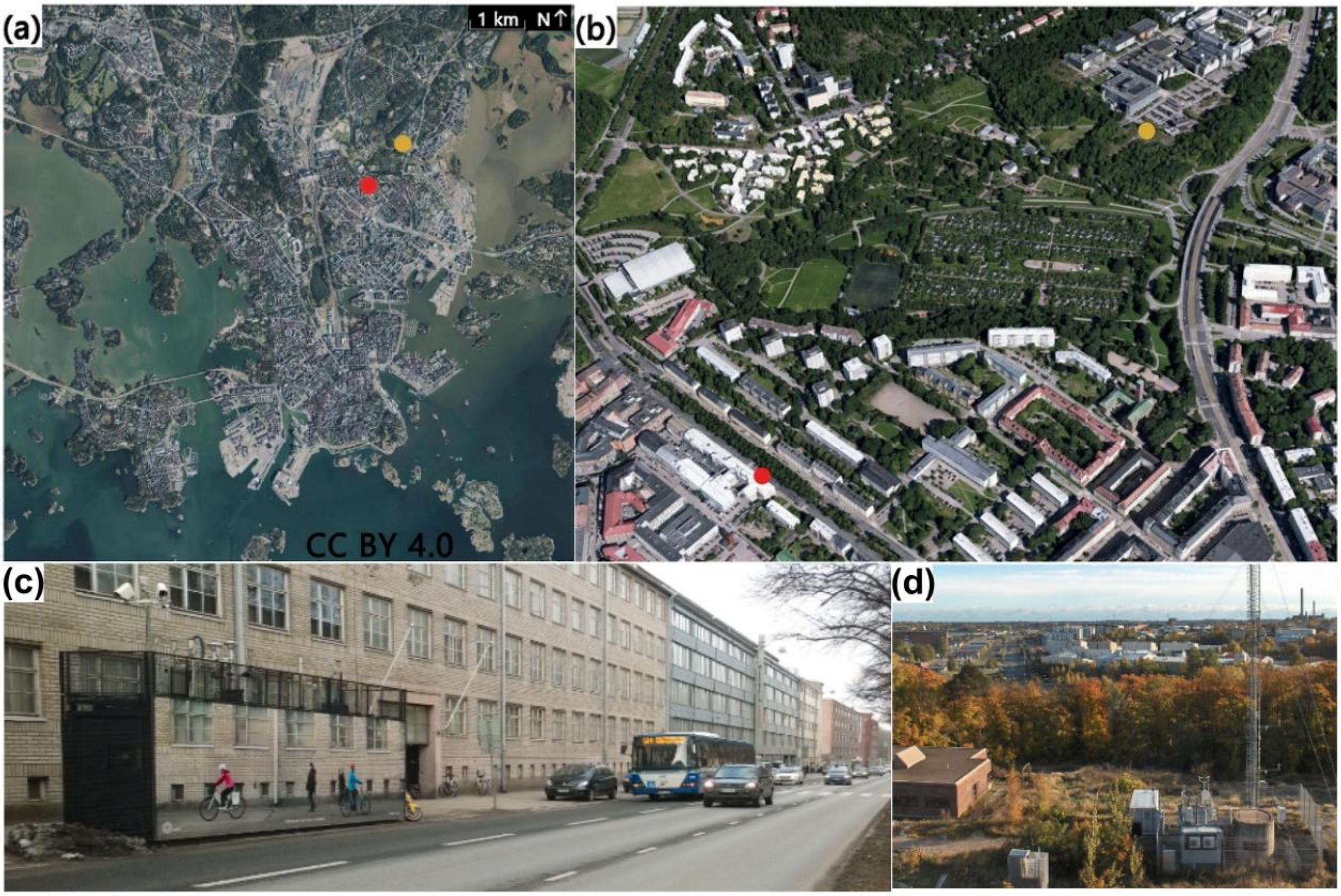

Figure 2.3.1. *Measurement sites in Helsinki. Red dot is Mäkelänkatu road-side site, while the yellow dot is the SMEAR III site located at Kumpula University Campus area. Panel (c) shows a view of the Mäkelänkatu site and panel (d) a view towards South-East of the SMEAR III site.*

2.3.2 Instrumentation & data

The SMEAR III site was established in 2004 to provide long-term measurements of the chemical and physical properties of aerosol particles, trace gas concentrations, and meteorological parameters in an urban background environment. The instruments are located in a container or a 31 m tall tower that is next to the container (Figure 2.3.1d). SMEAR III is an ACTRIS site and therefore follows the ACTRIS recommendations for sampling. The Mäkelänkatu site was established in 2015, and the set of measured variables is comparable to the SMEAR III site. The instruments are in a container that is next to a busy road (Figure 2.3.1c).

The PNSD at the SMEAR III station is measured by a Twin-DMPS system. The twin system consists of a Hauke-type DMA with a TSI Model 3756 CPC and a second Hauke-type DMA with a TSI Model 3772 CPC. The combined diameter range is 3-820 nm. The DMPS system at SMEAR III first became operational in August 2004. Mäkelänkatu site also has a DMPS system but it uses a single Vienna type DMA with an Airmodus CPC model A20. The measured diameter range is 6-800 nm and both the SMEAR III and Mäkelänkatu site provided NRT data delivery. Examples of NRT data appear in Figure 2.3.2.

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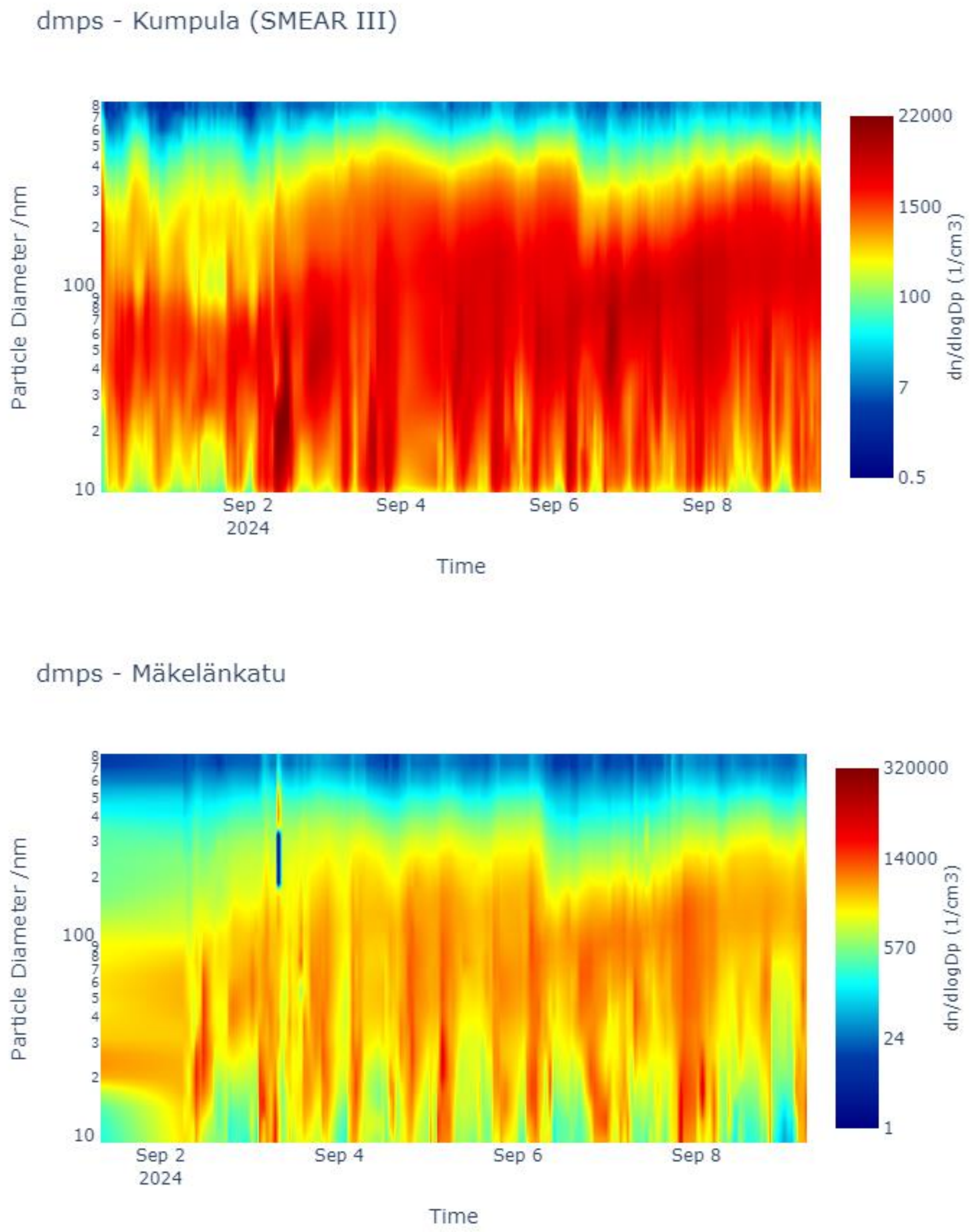

Figure 2.3.2. *A short sample of NRT size distributions measured in the Helsinki stations during the year trial of NRT as seen on the https://ebas-nrt.nilu.no/ website. Top panel: SMEAR III; lower panel: Mäkelänkatu.*

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2.4 Zurich

2.4.1 Site description: Kaserne

Zurich is the largest city in Switzerland with a population of 433,000 inhabitants. The total population for the area surrounding Zurich is about 1.1 million. Zurich is located between hills which channel the flow and provide a source of cool air at night and affect the diurnal cycle of the atmospheric boundary layer. Temperature gradients between the city and the lake of Zurich also affect the local circulation.

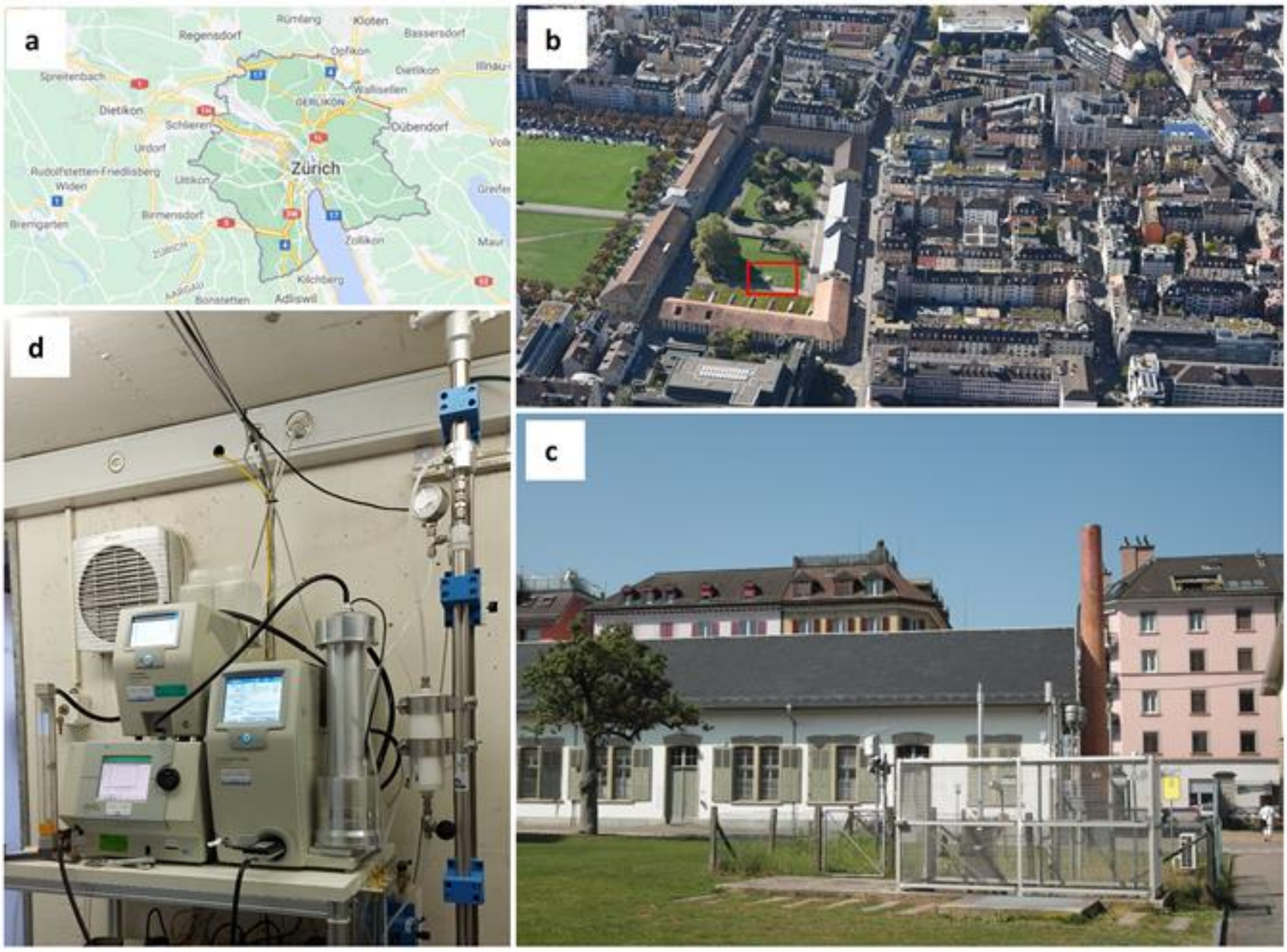

Figure 2.4.1. *Measurement site in Zurich. Panel a shows a map of Zurich and the surrounding area, panel b is an aerial view of the urban background site Zurich Kaserne (red rectangle). The instruments are installed in a room below ground level, from outside only the air inlets are visible (panel c). Panel d shows the MPSS inside the station, the system follows CEN and ACTRIS standards.*

PNSD measurements are conducted in the urban background site Zurich Kaserne. Zurich Kaserne is a site of the Swiss National Air Quality Monitoring Network NABEL. The station is located in the middle of the city of Zurich (approx. 500 m west of the main railway station) in a park-like courtyard, which is part of the building complex of the old barracks. The buildings and workshops of the former arsenal and barracks administration are located in the immediate vicinity. The adjoining quarter is mainly residential buildings as well as small businesses and stores. The measurement station is in a room below ground level, only the air inlets are visible from outside (inlet height is 4

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m). There are no roads in the immediate vicinity of the site, however, the traffic in the surrounding neighborhood is quite lively day and night. The meteorological parameters wind and global radiation are measured on a neighboring four-storey building.

PNSD measurements in Zurich were originally not planned in RI-URBANS but are a useful addition to the project. However, NRT data submission has not yet been completed, but is still in progress (the transmission of NRT data for total particle number measurements has been completed).

2.4.2 Instrumentation & data

PNSD measurements with an ACTRIS-compliant MPSS were started in June 2023. The MPSS consists of a dual polarity TSI-3082 classifier fitted with a DMA3083 (similar to the system in Birmingham) and a CPC 3750. Also similar to the Birmingham instrument is that the MPSS in Zurich samples off a 4-way flow splitter from a PM2.5 inlet (TSI 37500200) and covers the particle size range from 10 nm to 800 nm. A second CPC is directly connected to the flow splitter and measures total particle number concentration. The purpose of this second CPC is mainly the quality control of the MPSS, i.e. the observation of the accuracy of the particle number concentration derived from the integration of the size distribution. It should be noted that in the first weeks after the installation of the MPSS, a different type of CPC (TSI 3775, see Figure 2.4.1) was used to measure the total particle number concentration; thereafter, the CPC was replaced by the same type as that of the MPSS (CPC 3750).

Beside particle number distribution and total particle number concentration, measurements of a wide range of air pollutants and meteorological variables are measured at the Zurich Kaserne site.

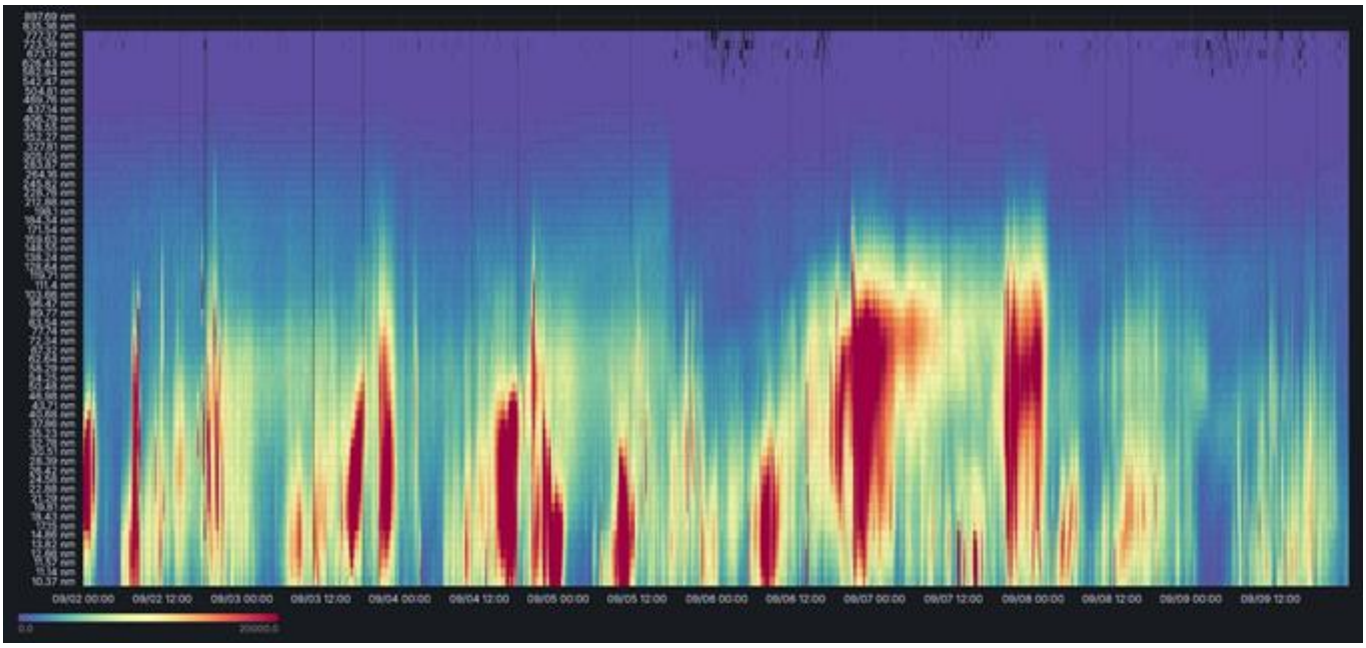

Figure 2.4.2. *A short sample of size distribution measurements at the Zurich station. Because NRT data transmission has not yet been completed, a screenshot of a graph in Grafana is shown.*

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3. Sustainability

Table 2 summarises the main achievements of the PNSD measurements in the five pilot cities of T.4.2. Showing that the objectives were met.

Table 2. Summary of the achievements of the Pilot Cities in T4.2

	BCN – Palau Reial	BIRM – BAQS	HEL – SMEAR III	HEL - Mäkelänkatu	ZUR - Kaserne ***
Upgrade to ACTRIS	✓	✓	✓	✓	✓
Calibration Dec 2023	✓	✓	✓	✓	✓
Implementation of NRT	28 Nov 2023	29 Nov 2023	18 Aug 2023	29 Aug 2023	×
Period of Operation of NRT*	278	277	380	369	×
Data Capture	77%	73%**	99%	78%	×

* Defined to 1st Sept 2024 (days).
** Accounting for instrument breakdown, e.g. requiring a TSI service, this can be potentially as high as 83-99%.
*** In operations since June 2023 with an 87% data capture. Zurich plans to submit NRT data not only from Kaserne but also from a suburban site.

For the three core sites the following **three strategic questions** were asked with regards the implementation and continued operation of the NRT at the sites. For each question, a summary of the answer follows.

- Was the upgrade to ACTRIS standards relatively easy or were there difficulties that need to be noted? Please comment on your experience.

Technical upgrade to ACTRIS standards was easy due to experienced personnel working with the instrumentation, support from manufacturer (eg TSI Instruments Ltd) and where there was prior experience on ACTRIS standards. For the TSI instruments the MPSS were first updated to ACTRIS standards to be able to work with positive voltage. Also, the DMA3083 needed to be purchased which covered the 10-800nm size range. In harmony with this, the CPC used with the SMPS and standalone CPC, we also needed to send it to recalibrate to a lower size limit of 10 nm. With regards to software, the TSI AIM software required updates to be able to export data in a format ready for the NRT. However, at a site where the experienced users are not operating the instrument, the upgrade could become challenging. In rolling out NRT to other sites, the ACTRIS Central Facility (e.g., aerosol in-situ calibration center) ought to be ready to deal with differences in the technical readiness levels of observation sites.

- Likewise, was the implementation of NRT easy or difficult and could you please comment on the process?

With regards to the implementation of the NRT software mixed messages were received with one site reporting that the implementation of NRT was rather straightforward, although there were delays in the steps. It took quite a while to see the NRT data in the ACTRIS data server. Updates and upgrades of the NRT software / version control were not optimally progressing. Additionally, we had the recommendation that personnel at both ACTRIS Central Facility and ACTRIS Data Center should be made available to speed up the implementation phase of NRT data delivery. It was noted that delays implementing the NRT with the TSI instruments was delayed because of difficulties because the NRT software was a prototype and needed to be adapted to TSI software export files and a further recommendation was that a more user-friendly software or more support from TROPOS would have reduced problems in our case. Currently, a working knowledge of PYTHON, script and a familiarity of the Command Prompt is useful. Although, a superficial knowledge is useful, a deeper understanding is needed which allows the user to understand the obscure return messages and to understand if the process is working or in troubleshooting mode. The screen grab below shows the Command Line screens used by the user of the NRT onsite. These may need interpretation for the inexperienced user.

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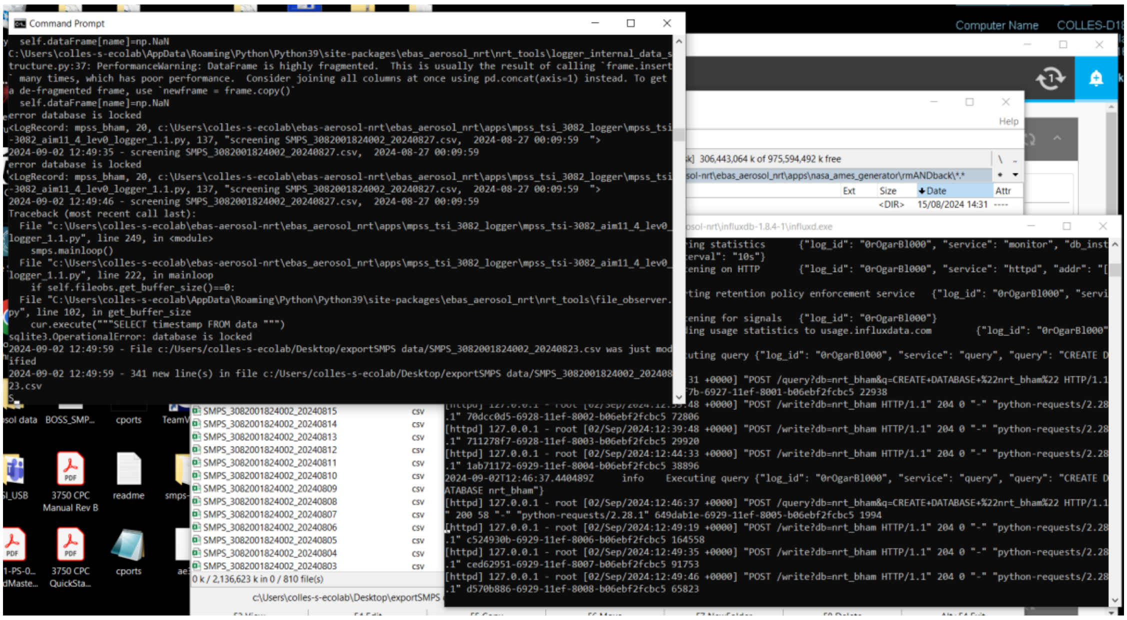

Figure 3.1.1. Command line screens used by the user of the NRT onsite.

- <u>Do you think that your site can continue to provide NRT MPSS data long term and what do you think will be needed to maintain a data flow to EBAS?</u>

The Birmingham site would indeed want to continue with a NRT MPSS data flow to EBAS with the possibility of extending this to other instruments. The limitation considered there will be with personnel to deal with the increase in difficulties that arise as additional instruments are put online. At Barcelona, the site will continue to provide NRT MPSS long term data to EBAS but requests a more user friendly software or more support to avoid problems if something changes in software/firmware or other errors occur. The Helsinki SMEAR III site can continue to provide NRT MPSS data long term, but more support would be needed if something changes in software/firmware or other errors occur. Ensuring the data delivery and data processing chain after software / firmware / hardware upgrades needs specific interaction between the data providers, Central Facility and Data Centre. The responsibilities should be discussed more clearly. Furthermore, a mechanism needs to put in place to more efficiently flag when data is not being submitted to EBAS. Currently, this relies on either the site operator looking on the EBAS NRT website or receiving an email from the Data Centre. An automated procedure would be recommended. In addition to the coresites, Zurich also plan to provide long-term data provision via NRT from Kaserne and from a second site. They have a second ACTRIS compliant system at suburban site in Duebendorf which is expected to measure long-term MPSS data from spring 2025. Hence Zurich is keen to have an easier way to implement NRT data submission.

4. Associated benefits for AQMNs and AQ policy

The New European Ambient Air Quality Directive (2024/2883/CE) requires the establishment of supersites with the ability to measure UFP and PNSD. This pilot has shown that experienced personnel can establish the measurement capability for UFP-PNSD and can implement the EBAS NRT software effectively. The demonstrates the capacity for AQMNs to establish their own capability, possibly with use of expert assistance in the set-up. Subsequent operation should be well within the capability of AQMN personnel. Once this has been established, a number of benefits follow.

- Cities will gain knowledge of their own status in terms of UFP concentrations and the likely exposures of their citizens. They will be able to view this in the context of other cities across Europe.

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- The data generated will be a valuable asset in the development of city-wide numerical models of UFP exposures.
- If regulatory standards or guidelines are developed for UFP, the data from the AQN will allow an assessment of local compliance, and an evaluation of the magnitude of possible mitigation measures needed if high concentrations occur. Additional value would arise from identification of new UFP hot spots, which are required to be monitored by the AQ directive.
- The data generated will be essential to establishing trends in UFP concentrations and evaluation of the impacts of control measures.
- The NRT capability will be a great asset if short-term mitigation measures are needed for the protection of public health during episodes.

In terms of policy development, a reliable, quality assured monitoring capability as established in the pilots is an essential component in the provision of evidence needed in any strategy for air quality improvement.

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