Comments from ACTRIS (and RI-URBANS) to DG ENV and AQUILA on the proposal for reviewing the EC Air Quality (AQ) Directives published on 26th October 2022

February 2023

This is a document containing preliminary recommendations from ACTRIS (and RI-URBANS) on this on the proposal for reviewing the EC Air Quality (AQ) Directives published on 26th October 2022. This document was elaborated by a group of experts from ACTRIS and RI-URBANS and we decided to send these preliminary comments now to adapt to the timing of the revision of the directive. From now, we will share this with the full ACTRIS community and a report will be produced in the near future.

The Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS) is directly mentioned in the draft proposal of the EC Air Quality (AQ) Directives published on 26th October 2022 with specific indications that, when appropriate, AQ monitoring shall be coordinated with the strategy and measurement programme of ACTRIS.

ACTRIS **is an ESFRI (European Strategy Forum on Research Infrastructures) landmark**[1]. The ACTRIS legal entity, established in Finland as a European Research Infrastructure Consortium (ERIC)[2], will be officially created in winter 2023, as **ACTRIS ERIC**, with the long-term political and financial commitment by **17 founding member and observer countries** (FI, IT, AT, BE, BG, CH, CY, CZ, DE, DK, FR, NL, NO, PL, RO, ES, SE)[3]. All countries participating in ACTRIS have well organised governing and managing structures at the national level. The National ACTRIS structures also exist as a joint research unit in Greece, the United Kingdom and Portugal, not yet formally committed to establish ACTRIS ERIC. **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 air quality studies**[4].

ACTRIS focuses on **variables not regulated by the current EC directive.** It is unique in Europe in providing **operational data value chain for more than 50 advanced atmospheric variables**, at near-surface, integrated column or profile, from approximately **100 facilities** located in different environments (remote, coastal, regional background, peri-urban, urban). Generally, the operational data value chains consist of **standard operating procedures (SOPs)**, **implementation** at National ACTRIS facilities (ACTRIS NF)[5], **quality control** by ACTRIS Topical

[1] ESFRI roadmap for Research Infrastructures 2021 https://roadmap2021.esfri.eu

[2] Information on European Research Infrastructure Consortium: https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/our-digital-future/european-research-infrastructures/eric_en

[3] https://www.actris.eu

[4] https://www.actris.eu/catalogue-of-services

[5] https://www.actris.eu/facilities/national-facilities

Centres (ACTRIS TC)[6] and **free-access** to different level products through a single-entry point ACTRIS Data Centre (ACTRIS DC)[7] (Figure 1). Several ACTRIS variables are currently available in Real-Time as a product for application in Copernicus Atmosphere Monitoring Service (CAMS). ACTRIS actively works with metrology institutes in Europe, with the Centre for European Normalisation to define **reference standards for non-regulated variables,** and with international agencies such as the World Meteorological Organization (WMO) to ensure **global scale application of the ACTRIS recommended observation and access procedures**. The list of the ACTRIS variables is annexed to this document.

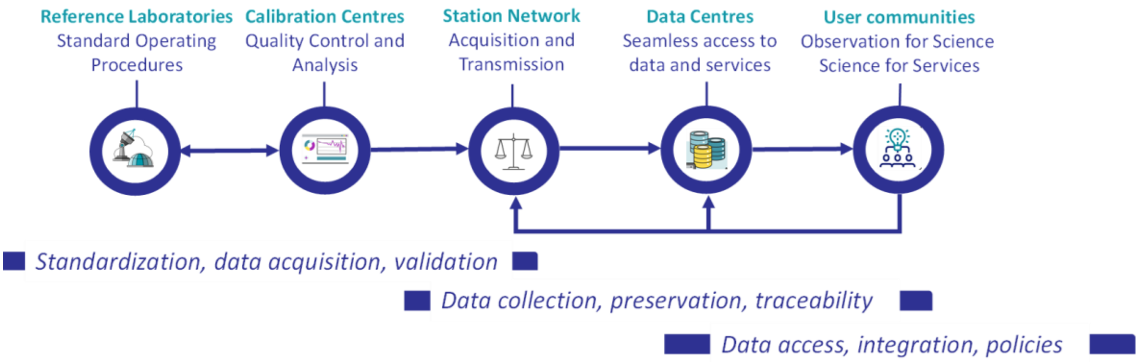

Figure 1: The ACTRIS value chain from definition of standard operating procedures to access. The value chain is in-place for almost all 54 variables listed in the Annex of this document.

In 2021, the European Commission mandated ACTRIS to further develop specific services for the urban environments, as part of the EU Green Deal strategy. The **RI-URBANS** project, funded by the H2020 programme (2021-2025), has a specific objective to demonstrate how ACTRIS service tools can be adapted and enhanced to better address the challenges and societal needs concerning the **air quality in European cities and industrial hotspots**. Based on pilots performed in 9 European cities, RI-URBANS will provide recommendations on most suited strategies to evaluate, predict and support policies for abating urban air pollution, as well as to transfer novel service tools to support decision-making by AQ managers and regulators, including their potential implementation in EC AQ directives. RI-URBANS focuses on ambient nanoparticles and atmospheric particulate matter, and their gaseous precursors and develops specific tools to evaluate new AQ parameters, source contributions, and their associated health effects (Figure 2). RI-URBANS is ongoing and it is expected that the first recommendation from ACTRIS / RI-URBANS will be available as early as mid-2023.

The **proposal of the revision of the most recent EC AQ Directive calls for an enhanced coordination with the strategy and measurement programme of ACTRIS.** In view of the expertise of ACTRIS-RI-URBANS on the topics regulated by Articles 8 and 10 and the VOCs (Annex VII) of the proposal of revision, we have agreed in sending to Directorate-General for Environment (DG-ENV) a number of comments on these. **The purpose of the present document, prepared by a team of experts in ACTRIS and RI-URBANs, is, therefore, to indicate the current level of preparedness of relevant ACTRIS tools to be incorporated in EC AQ Directives and to formulate a series of recommendations for ensuring the most suited ways to capitalise the**

[6] https://www.actris.eu/topical-centre/cars
[7] https://www.actris.eu/topical-centre/data-centre

ACTRIS and RI-URBANs service tools (including expertise and know-how) and their integration in a future directive.

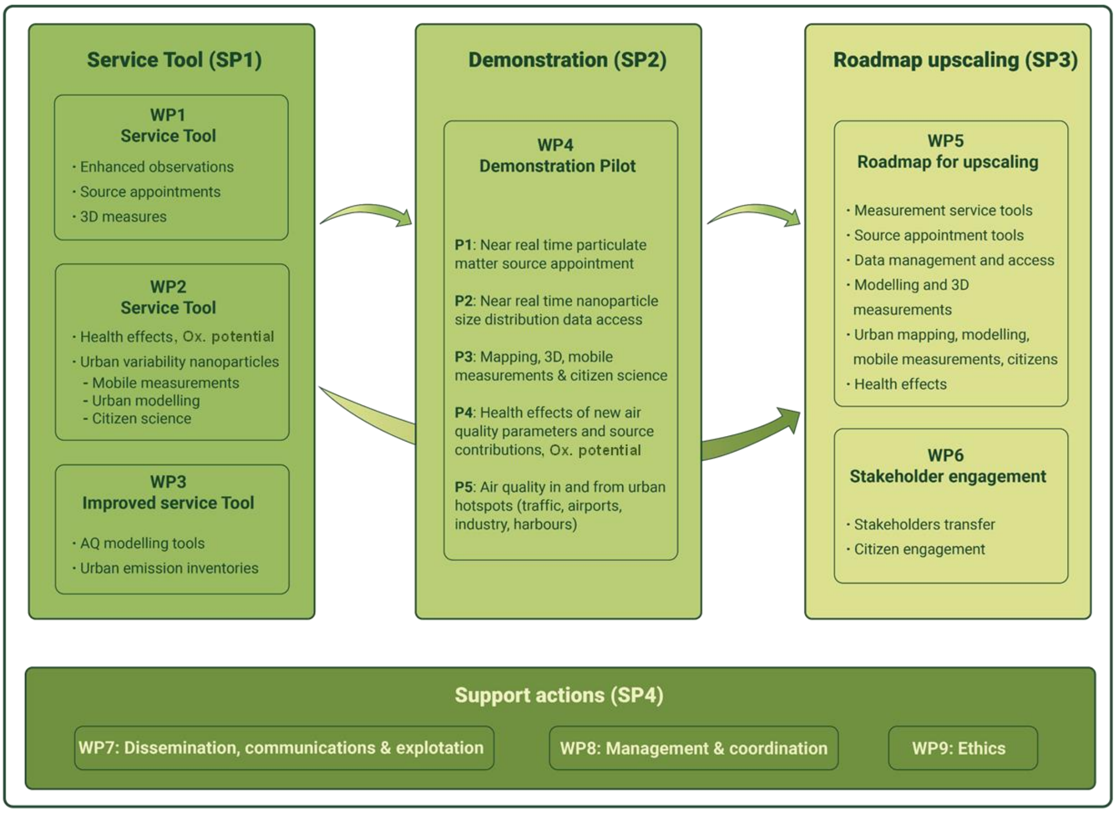

Figure 2: The RI-URBANS concept with major pillars and WPs and advanced AQ service tools demonstrated.

The focus in the document is on **Ultra-Fine Particles** (UFP), **Particle Number Size Distribution** (PNSD), **Black Carbon** (BC), **online and offline speciation of Particulate Matter** (PM), **Volatile Organic Compounds** (VOCs), **Ammonia** (NH_3), **Oxidative Potential** (OP) and **aerosol vertical profile** (AVP, not included in the proposal of review for supersites but recommended by ACTRIS / RI-URBANS), all relevant to ACTRIS and RI-URBANS. The document also addresses the **coordinated use of ACTRIS National Facilities** in the network of supersites in urban and rural background environments defined in Article 10.

1. We highly recognise and appreciate that:

i) There is a willingness to extend the AQ directive to currently non-regulated pollutants, which may be very relevant for the future development of AQ regulations, the evaluation of the impacts of air pollution on health, the better evaluation of the effects of AQ policies, and ultimately to the well-being of European citizens.

ii) UFP, PNSD, BC, OP, NH_3 and PM speciation have been included, as well as the listed PAHs and an extended list of VOCs, in addition to other regulated pollutants.

iii) A network of European super-sites is proposed to be created with similar objectives to the one established, with extremely good results, in the US by the US-EPA, to support environmental and scientific policy studies.

iv) This is a timely proposal given the currently ongoing developments within ACTRIS and RI-URBANS to demonstrate the added-value of observing the non-regulated pollutants for AQ management and the development and testing of innovative tools for AQ monitoring in relation to human health.

Notably, the EC AQ Directive will be established with ACTRIS ERIC in operation, reinforcing the capacity to operate ACTRIS National Facilities and AQMN supersites in synergetic ways, including joint management of advanced data and tools, already operational within ACTRIS.

2. General comments on sites and pollutants

2.1 Extending AQ directive to new pollutants and integrating the concept of supersites

The implementation of measurements and supersites in accordance with the requirements of Articles 8 and 10 of the proposed revision of the directive will entail very significant economic costs for the member states, as well as a paradigm shift in the maintenance of observing stations. Some of the measurements, such as UFP, PNSD and VOCs, require an exhaustive control and specific calibrations, different from those of the regulated pollutants, and for this, specific and significant budget items must be allocated, and the funding source must be identified Moreover, the substantial volume of data generated by the new variables will require data management methods that are probably different from the existing ones.

***Recommendation #1**: It is fundamental to seek synergies with the existing infrastructure in place and ACTRIS in particular. For example, the budget for centrally operating the ACTRIS DC system is* 3,9 M€ *annually* in operational phase (including both implementation and operation costs)*, while the cost of operating a National Facility is 1 to 3 M€ annually and the annual budget for operating the six ACTRIS TCs is approximately 10,8 M€. Substantial economies can be achieved by coordinating actions in the various countries as tested within RI-URBANS.*

ACTRIS agrees with the suggested list of new pollutants indicated in the draft Proposal. More widely performed observations of UFP, PNSD, BC, speciation of PM, VOCs, NH_3, and OP in urban and peri-urban areas, have the potential to better identify emission sources harmful to human health and to help decision-making in AQ management[8]. In addition, it may be important to consider integrating the vertical aerosol profile as a recommended variable. One key stressor to deteriorating AQ is, on the one side, vertical diffusion of pollutants and, on the other, subsidence of PM transported over long-distances. In both cases, monitoring the presence of aerosol vertical layers, in particular for events like biomass burning, may be essential. ACTRIS also fully appreciates that the new directive will permit monitoring of key constituents influencing both air quality and climate, recognized as essential climate variables in the new Global Climate Observing System (GCOS) implementation plan[9].

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.

[8] Dallenbach et al., 2020. https://www.nature.com/articles/s41586-020-2902-8
[9] https://library.wmo.int/index.php?lvl=notice_display&id=22134#.Y7L08y_pMdg

Therefore, we recommend 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. Alternatively, or in addition, wind lidars that can measure vertical profiles of wind will enable numerical models to better forecast air pollution once assimilated.

Recommendation #2: *Maintain the provisional list of non-regulated pollutants in the new directive and add provision of information on the aerosol vertical profile to be monitored at supersites.*

2.2 Ensuring science-based community-agreed operating procedures for the measurements of non-regulated pollutants

Since more than a decade, the research community in ACTRIS has been leading initiatives to define standard references and operating procedures, quality objectives, control checks and best practice for measurements, as well as access to data and data products, in collaboration with relevant CEN working groups or EMPIR projects. While ACTRIS can currently provide science-based community-agreed methods for many non-regulated pollutants, it is important that methodologies for the provision of UFP, PNSD, BC, online and offline speciation of PM, VOCs, NH_3, OP, AVP are agreed based on the experience from RI-URBANSS pilots whenever established references and/or accepted standard operating procedures are not fully available.

Recommendation #3: *Capitalise, whenever possible, from the measurement metrology outcome from past and current projects, in particular from ACTRIS-1, ACTRIS-2 and RI-URBANS in order to ensure implementation of the most suited operating procedures and interoperability between observations performed by all networks in Europe and beyond.*

ACTRIS has Topical Centres (TCs) for BC, UFP, PNSD, AVP, VOCs that have been operating for years with particular duties to defining procedures and tools for quality assurance and quality control of ACTRIS measurements and data, ensuring training and transfer of knowledge to ACTRIS operators, users, and to CEN working groups, and improving measurement methodologies for aerosol, clouds and reactive trace gases. TCs are set up to respond to the scientific and technical needs of ACTRIS, and to control operations at the National Facilities.

There are still scientific and technological questions to be resolved for specific pollutants before standard operating procedures can be agreed upon. While SOPs for the sampling and analysis of Polycyclic aromatic hydrocarbons (PAHs) are well established, there are still discussions on other pollutants indicated in the document. We can give several examples:

i) The current WHO Air Quality Guidelines[10] state that the results on the health effects of UFPs are inconsistent, although there are indications that these may be harmful. The guidelines propose a greater extension of the measurements for UFP so that, in the future, the effects on human health might be evaluated with less uncertainty. Several policy documents[11] and papers[12]

[10] https://apps.who.int/iris/handle/10665/345329

[11] White Paper: Ambient ultrafine particles: Evidence for policy makers: https://efca.net/files/WHITE%20PAPER-UFP%20evidence%20for%20policy%20makers%20(25%20OCT).pdf

[12] Rivas et al. (2020): https://www.sciencedirect.com/science/article/pii/S016041201931832X

indicate inconsistency of the measurement methods and conditions and limited observations as a cause for inconsistencies.

ii) BC measurements can be of great value for the study of the effects on health of specific combustion emission sources, at the same time these can be greatly affected by the mitigation measures and actions. It is closely related to the mass concentration of Elemental Carbon (EC), which is chemically determined. Commercial instruments are available but comparability of the BC measurement data from different sites is greatly affected by variability in the MAC (Mass Absorption Cross-Section) coefficient that shall be used to convert the absorption values into mass of BC, commonly designated as equivalent BC (eBC, RI-URBANS, 2022a and b). In terms of AQ, eBC and EC are meant to be tantamount. There is also a need for the adoption of a reference standard, a key objective of several metrology projects[13].

iii) Measurements of NH_3 in urban and rural areas are considered of great interest, since this gaseous pollutant plays a key role in the formation of ammonium sulphate and nitrate, two important components of PM2.5. Currently, there are very few measurements of NH_3 in urban environments but most studies agree it is key to reduce its levels to abate urban PM2.5. Commercial instruments are available for off-line and online determination of NH_3[14] but only the off-line technique has accepted standard operating procedures[15].

iv) OP (oxidative potential) measurements are novel but of great importance to identify the components and sources of PM10 and PM2.5 having a greater capacity to cause oxidative stress when inhaled[16]. Oxidative stress is known as a key factor leading to the observed cardio-respiratory outcomes seen in exposed populations. This may allow policy makers to target the most concerning sources including PM mass and their oxidative capacity in the human respiratory system. However, the measurement of the OP can be carried out with a wide variety of techniques and methods, and, currently there are no accepted standard operating procedures nor commercially available instruments. RI-URBANs will provide the first recommendation for widely developing and operating OP observations in Europe.

Recommendation #4: *Advance with the scientific community to define the SOPs for the new pollutants and rely on the already established ACTRIS TCs whenever relevant.*

The Annex VII of the EC AQ Directive proposes an updated list of VOCs including oxygenated compounds and terpenes. VOCs are of interest considering their role in O_3 formation but also in Secondary Organic Aerosols (SOA) formation. The collocated measurement of VOCs together with UFP measurements can be recommended at supersites in order to better identify/apportion sources and understand processes of new particle formation and growth. Additional species can be measured depending on the objectives sought, and on the instrument deployed for VOCs measurements (like Proton Transfer Reaction Mass Spectrometry / PTR-MS). ACTRIS implements a Topical Centre Unit for VOCs measurements able to provide the most suited recommendation for the specific VOCs to be measured.

Recommendation #5: *Propose measurement protocols for VOCs species capitalising from the scientific and technical experience of CEN WG13, AQUILA and ACTRIS.*

[13] http://www.empirblackcarbon.com/news-and-events/

[14] Marsailidh et al., 2022: https://amt.copernicus.org/preprints/amt-2022-107/amt-2022-107.pdf

[15] US-EPA NH_3: https://www3.epa.gov/ttnemc01/ctm/ctm-027.pdf

[16] Yanoski et al., 2012: https://pubs.acs.org/doi/10.1021/es3010305

Many of the new pollutants indicated in the draft of the revision of the EC AQ Directive are climate-forcers[17]. Some short-lived reactive gases and particulate matter are detrimental to human health and have complex characteristics, which can either cool or warm the atmosphere. For example, Aerosol Light Extinction Vertical Profile, Chemical Composition of Aerosol Particles, Aerosol Number Size Distribution and Aerosol Single Scattering Albedo listed as Essential Climate Variables by GCOS[18] are either identical or connected to AVP, online and offline speciation of PM, PNSD, and (e)BC listed in the draft of the revision. Policy changes that seek to improve air quality thus have repercussions on those policies that seek to limit climate change, and vice versa. The establishment of the new directives must consider the United Nations Framework Convention on Climate Change (UNFCCC) policies in defining SOPs and favour interoperable data chains that serve both policies.

Recommendation #6: *Ensure a high level of interoperability between the data value chain for responding to AQ and Climate policies. Some of these issues could be resolved with a greater interrelationship between DG. Environment and DG. Research.*

3. Number of supersites

Based on the criteria of Articles 8 and 10, the following supersites and UFP-equipped AQ monitoring sites (AQMS) are estimated for a number of countries as examples:

			Spain	France	UK	Romania	Germany	Hungary	Italy	Finland
Art10	Supersites	UB	5	7	7	2	8	1	6	1
Art10	Supersites	RB	5	6	2	2	4	1	3	3
Art8	AQMS-UFP	Hotspot	10	14	13	4	16	2	12	1

• **Urban supersites (UB)** equipped with measurement of **PNSD**, UFP, (e)BC**, OP,** PM10, PM2.5, NO_2, O_3, NH_3, As, Cd, Ni, BaP, PAHs, Hg(g) and PM2.5 speciation.

• **Rural supersites** (RB) equipped with UFP, (e)BC, PM10, PM2.5, NO_2, O_3, NH_3, As, Cd, Ni, BaP, PAHs, Hg(g) and PM2.5 speciation.

• **UB and RB sites:** Fixed or indicative measurements of deposition of As, Cd, Hg, Ni, BaP and the mentioned PAHs

• **AQMS-UFP:** Equip an existing one or install a new AQMS with UFP measurement in pollution hotspots.

ACTRIS is operating approximately 100 facilities, located in different environments from remote, to rural to peri-urban to urban, that are currently monitoring these parameters. Furthermore RI-URBANS includes other non-ACTRIS urban supersites that in the near future will supply data to ACTRIS.

Recommendation #7: *Based on the experience gained in ACTRIS and RI-URBANS, and on the scales of regional climate variations, we believe that the number of super-sites proposed in the review of the directive could be reduced by a half, while keeping in mind the need to cover*

[17] https://public.wmo.int/en/media/press-release/wmo-air-quality-and-climate-bulletin-released-clean-air-day
[18] https://library.wmo.int/index.php?lvl=notice_display&id=22134#.Y8aZRHbMKUk

relevant climatic regions and cities, and keeping at least one of each even in small countries. Likewise, the stations with monitoring of atmospheric deposition could be reduced by half.

Recommendation #8: *Ensuring the establishment of supersites recommended in the draft document made through capitalising upon existing facilities, and in particular the ACTRIS National Facilities as RB or UB sites. RI-URBANS addresses joint exploitation of operations with AQMNs, also including data policies.*

Recommendation #9: *Clarify the definition of monitoring sites, and in particular the rural sites, i.e. whether RB stations are located in small towns in rural settings, or do they include regional background stations in rural settings but separated from the rural population? It would be good to define what are the objectives of the measurements in urban and rural environments. For urban sites the objective seems more obvious, but it is not so clear for rural supersites.*

4.6. Other general recommendations

i) European coordination and guidance are required to maintain pan-European harmonisation. It is important that a European and National coordination is followed for the implementation of supersite networks to ensure harmonisation of instrumentation, measurement and analytical procedures, especially in techniques that do not have a reference method.

ii) According to Article 10, ACTRIS has relevant 'roles', however these are not defined. These have to be defined in terms of tasks, budget associated and the sources of the budgets. It is also relevant to include AQUILA and EEA in this definition in order to clarify their individual roles.

iii) Synergies between AQMNs and ACTRIS are central to RI-URBANS, which will test governance models based on pilot operations in 9 European cities. Rationalising countries' investments for developing the AQ monitoring system will require capitalising from the existing infrastructure (ACTRIS monitoring sites, Data Centre, Topical Centres). We believe that ACTRIS should have a key role for the implementation and governance structure of a future AQ observing system, also in terms of guidance to identify proper instrumentation, protocols, measurement certification criteria, QA/QC for the realisation of a FAIR data management system connected to ACTRIS DC and TCs. Resources will be needed to co-construct the most appropriate system supporting the AQ directive.

Recommendation #10: *Engage in co-constructing the most appropriate data value chain system supporting the implementation of the EU directive on AQ mobilising the scientific community through the Research Infrastructure ACTRIS, and capitalising from the existing system and the work in RI-URBANS.*

5. Technical recommendations

5.1. UFP measurement

We consider very relevant to clarify that UFP or nano-particles are scientifically defined as the particle number concentration (PNC) of particles <100 nm. The proposal of revision of the directive defines UFP as PNC of particles of a size ≥ 10 nm, without a top coarser size detection limit. This definition is adequate for PNC but not for UFP. It is advisable to cite in the directive the CEN (European Committee for Standardization) and ACTRIS recommendations so that at least these are followed for the measurement of total UFP. Specifically, we refer to CEN/TC 16976:2016[19] and ACTRIS[20] for total UFP. See RI-URBANS UFP section [21].

It is important to define what lower limit is intended to be obtained for the UFP measurements. The proposal defines 10 nm or less, but this limit rules out 50% of the nucleation mode (<20nm) and we cannot rule out, a priori, that these finest UFPs have no effect on health. However, CEN recommendations fix this at 7 nm. This CEN/TC is under revision, and 10 nm is the new recommendation. It will become an EU Standard by 2024. ACTRIS is already adapted to 10 nm due to the current implementation phase.

Technical recommendation #1: *Accordingly, we recommend following CEN and ACTRIS recommendations and start measurements of the condensation particle counters (CPC) at 10 nm, but if the supersite is willing to provide data on nucleation mode PNC, complement the CPC with a nano-CPC to obtain by difference the 3-10 nm size.*

5.2. PNSD measurement

As for the UFPs, it is important to define what lower size limit is intended to be detected for the PNSD measurements. The proposal defines 10 nm or less, but this limit rules out 50% of the nucleation mode (<20nm) and we cannot rule out a priori that these finer UFPs have no effect on health. RI-URBANS showed that the existing supersites use lower size detection limits from 3 to 17 nm across urban Europe. Starting in one range or another can make a 20% difference in total UFP concentration, but >60% in the nucleation mode UFPs.

Also, as for UFP, it is advisable to cite the CEN and ACTRIS method in the proposal so that they are at least followed for the PNSD measurement. Specifically, we refer in this case to CEN/TS 17434:2020[22] for PNSD and ACTRIS[23] (2021). See RI-URBANS' PNSD section[24] that adapts and discusses these recommendations for the measurement of urban AQ.

Technical recommendation #2: *RI-URBANS recommends starting from 3 nm, at least, in order to independently assess the effect of nucleation mode (<20 nm) on health, and if this effect is not consistent, in future starting at 10 nm. However, CEN recommendations set the lower limit at 10 nm. ACTRIS recommends 10-800 nm. Only for sites with a focus on sub-10 nm particles, an additional instrument is considered. RI-URBANS recommendation is adding an additional instrument (nano-CPC, Particle Size Magnifier-PSM,...) to evaluate the concentrations of the nucleation mode particles. Thus, we recommend starting measurements with Mobility Particle Size Spectrometers (MPSS) and CPC from 10 nm, following CEN and ACTRIS recommendations,*

[19] https://www.en-standard.eu/pd-cen-ts-16976-2016-ambient-air-determination-of-the-particle-number-concentration-of-atmospheric-aerosol/

[20] https://www.actris.eu/sites/default/files/2021-06/Preliminary%20ACTRIS%20recommendations%20for%20aerosol%20in-situ%20measurements%20June%202021.pdf

[21] https://riurbans.eu/wp-content/uploads/2022/10/RI-URBANS_D1_D1_1.pdf

[22] https://www.en-standard.eu/une-cen-ts-17434-2020-ambient-air-determination-of-the-particle-number-size-distribution-of-atmospheric-aerosol-using-a-mobility-particle-size-spectrometer-mpss-endorsed-by-asociacion-espa-ola-de-normalizacion-in-may-of-2020/

[23] https://www.actris-ecac.eu/actris-gaw-recommendation-documents.html, Preliminary ACTRIS recommendations for aerosol in-situ sampling, measurements, and analyses (V.3)

[24] https://riurbans.eu/wp-content/uploads/2022/10/RI-URBANS_D1_D1_1.pdf

and adding an additional instrument to obtain the <10 nm fraction that will give a more complete picture of the nucleation mode fraction.

IMPORTANT: Most of this equipment has a radioactive source of ^{85}Kr. This entails additional expenses for the annual licence and for the precautions to be taken and rules to be followed in handling radioactive sources. As an option there are XR-neutralizers but these are not recommended for long term observations by the expert community. ^{63}Ni-neutralizers are now being manufactured, but their market penetration is still low. With an activity of less than 100 MBq, these are under the free limit and do not need a licence if used as only radioactive source at the site. will probably be widely available, and probably will have much fewer problems than the XR ones.

5.3. (e)BC and EC measurements

BC mass concentration can be estimated using absorption photometers (aethalometer being the most common instrument) if the measurement is carried out online or by the specific CEN standard if **Elemental Carbon (EC)** is measured both online or off-line. We refer to the scientific literature for proper definition of eBC[25].

Its measurement and maintenance are relatively simple. However, it is extremely relevant to define how to convert the absorption units/m^3 (into µg/m^3) provided by the instrument. The use of different types of MACs can give differences of up to 60% for the same measurement as demonstrated by numerous studies including ACTRIS[26]. ACTRIS is also addressing, together with Metrology Institutes in Europe, the definition of agreed standard for (e)BC.

There are two major options: i) using a default MAC value (e.g., the one proposed by the instrument firmware, not recommended by the ACTRIS protocols), or ii) using experimental MAC values obtained in situ with comparisons with simultaneous measurements with the EC of PM2.5. See RI-URBANS section on BC[27, 28]. We remind at this point that EC will be measured in the same supersite according requests of Article 10. ACTRIS has supplied an average MAC value that is recommended to be used (not the instrumental one) if the supersite cannot obtain the in situ determined MAC.

Technical recommendation #3: *We recommend that a locally obtained MAC is used for each instrument and site, being obtained by in situ co-measuring EC and eBC. When this is not possible, then use the average ACTRIS MAC. However, discussion on the most suitable operation procedures for the determination of (e)BC would start from the recommendation from ACTRIS/RI-URBANS which will soon be published.*

5.4. OP's measurement

OP is measured by contacting airborne particles with pulmonary fluids containing antioxidants or surrogates (dithiothreitol, ascorbic acid or glutathione are the most used). The lungs display different antioxidants that do not react in the same way to different PM compounds, so that ascorbic acid (AA) has been described as the greatest tracer of OP for metals, although dithiothreitol (DTT), a thiol component more balanced towards organics and metals, is the most

[25] Petzold et al., Atmos. Chem. Phys., 13, 8365–8379, 2013, https://doi.org/10.5194/acp-13-8365-2013
[26] Zanatta et al., Atmos. Envir., https://doi.org/10.1016/j.atmosenv.2016.09.035
[27] https://riurbans.eu/wp-content/uploads/2022/10/RI-URBANS_D1_D1_1.pdf
[28] https://riurbans.eu/wp-content/uploads/2022/10/RI-URBANS_M1.pdf

widely used in AQ studies. The incubation time is also important, and the sample storage conditions from sampling to analysis (it must always be frozen). These assays are mainly performed off-line from PM filters, but new online research prototypes appear. See RI-URBANS' section on OP[29].

It is vital to set the measurement conditions and protocols to be used in the OP measurement to assure comparable results. A first Pan-European intercalibration of OP techniques is set to take place in Jan. 2023 as part of RI-URBANS, providing important results. Integration of OP as an ACTRIS variable is being discussed.

Technical recommendation #4: *Make use of the first recommendation from RI-URBANS and engage with the academic community to define the most suited OP techniques and their standard operating procedures before engaging in CEN initiatives.*

5.5. NH_3 measurement

Although excess reactive nitrogen in the environment has been demonstrated to have environmental impacts[30], NH_3 is currently not included as an ACTRIS variable, although this may evolve considering national initiatives in ACTRIS. Measurements of NH_3 in cities are still scarce[26] and a number of AQ networks which acquired online NH_3 equipment are facing many operational problems when obtaining long time series.

Off-line measurements constitute the current reference method of the European Monitoring and Evaluation Programme with the disadvantages of not providing high temporal resolution information, being labour intensive and susceptible to handling and storage artefacts. CEN TC 264 WG 11, N 17346:2020 «Ambient air - Standard method for the determination of the concentration of ammonia using diffusive samplers», specifies a method for the sampling and analysis of NH3 in ambient air using diffusive sampling.

Online techniques are more suited although defining SOPs still will require work in the research community. Quality procedures will possibly require definition of metrological standards. Recent work in the research community[31] provided evidence that, although NH_3 instrumentation has greatly progressed in measurement precision, there is still further work required to quantify the accuracy of these systems under field conditions.

Technical recommendation #5: *Opt for online NH_3 standard technique and engage with the research community to define requirements and the most suited standard operating procedures also including inlet setup, calibration, and routine maintenance in order for datasets to be comparable.*

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[29] https://riurbans.eu/work-package-2/

[30] European Nitrogen Assessment (ENA) (Sutton et al., 2011). http://www.nine-esf.org/node/360/ENA-Book.html

[31] Twigg et al., Atmos. Meas. Tech., 15, 6755–6787, 2022, https://doi.org/10.5194/amt-15-6755-2022

Annex: List of ACTRIS variables

Aerosol in situ

- Particle light scattering and backscattering coefficients
- Particle number size distribution - mobility diameter
- Particle number size distribution - aerodynamic diameter
- Particle light absorption coefficient and equivalent black carbon concentration
- Particle number concentration
- Nanoparticle number size distribution
- Nanoparticle number concentration
- Cloud condensation nuclei number concentration
- Mass concentration of particulate organic and elemental carbon
- Mass concentration of particulate organic tracers
- Mass concentration of non-refractory particulate organics and inorganics
- Mass concentration of particulate elements

Trace gases in-situ

- NMHCs
- OVOCs
- Terpenes
- NO
- NO2
- Condensable vapours

Aerosol remote sensing

- Attenuated backscatter profile
- Volume depolarization profile
- Particle backscatter coefficient profile
- Particle extinction coefficient profile
- Lidar ratio profile
- Ångström exponent profile
- Backscatter-related Ångström exponent profile
- Particle depolarization ratio profile
- Particle layer geometrical properties (height and thickness)
- Particle layer optical properties (extinction, backscatter, lidar ratio, Ångström exponent, depolarization ratio, optical depth)
- Column integrated extinction
- Planetary boundary layer height
- Spectral Downward Sky Radiances
- Direct Sun/Moon Extinction Aerosol Optical Depth (column)
- Aerosol columnar properties
- Aerosol profile microphysical and optical properties

Trace gases remote sensing

- Ozone partial columns
- Ozone column
- Formaldehyde column

- Formaldehyde lower tropospheric profile
- NO_2 column
- NO_2 lower tropospheric profile
- NH_3 column
- C_2H_6 column
- SO_2 lower tropospheric profile
- SO_2 column

Cloud profile variables

- Cloud/aerosol target classification
- Drizzle drop size distribution
- Drizzle water content
- Drizzle water flux
- Ice water content
- Liquid water content
- Liquid water path
- Temperature profile
- Relative humidity profile
- Integrated water vapour path

Cloud in situ variables

- Liquid Water Content
- Droplet effective diameter
- Droplet number concentration
- Droplet size distribution
- Interstitial aerosol number concentration
- Interstitial aerosol size distribution
- Total aerosol number concentration
- Total aerosol size distribution
- Cloud residuals number concentration
- Cloud residuals composition
- Ice particle number concentration
- Ice particle size distribution
- Ice nucleating particle number concentration
- Ice nucleating particle temperature spectrum
- Bulk cloud water chemical composition