



Deliverable D4.2

A Compendium of Pilot Reports and Findings

Work Package 4

MONITOR – Pilots, data and campaigns

Version: Final



This project has received funding from the European Union's
Horizon Europe Framework Programme under grant agreement N° 101057497.

Deliverable Overview

Deliverable 4.2 offers an overview of the pilots and campaigns, detailing how each achieved its individual targets, the data generated, and instructions on accessing and utilising this data for future research. Task 4.2, “Pilots and campaigns”, primarily focused on establishing the infrastructure and gathering data. As the pilots and campaigns are interconnected with other work packages, some analyses and key findings from the pilots and campaigns will be presented in WP3 (Science) and WP5 (Tox and Health).

Additional Information

Type: R – Document, report

Dissemination Level: PU – Public

Official Submission Date: 31st of July 2025

Actual Submission Date: 31st of July 2025

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Document Revision History

Version	Date	Description	Partners
V1.0	30.06.2025	1 st draft of deliverable	Taltech
V1.1	08.07.2025	1 st quality review	LC
V2.0	10.07.2025	2 nd draft of deliverable	Taltech
V2.1	24.07.2025	2 nd quality review	ANT, IMROH
FINAL	28.07.2025	Final quality review	LC
FINAL	31.07.2025	Final version	Taltech

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This project has received funding from the European Union's Horizon Europe Framework Programme under grant agreement N° 101057497.

Statement of Originality

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.



This project has received funding from the European Union's Horizon Europe Framework Programme under grant agreement N° 101057497.

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1 Executive Summary

The EDIAQI project aims to enhance indoor air quality (IAQ) across Europe through data collection, analysis, community engagement, and the development of policy recommendations. Deliverable D4.2 of the EDIAQI project summarises the four pilots and four campaigns, highlighting their objectives, activities, and key results.

The project included four pilots and four campaigns:

Pilots

- Ferrara Pilot: Focuses on monitoring the main parameters and pollutants of IAQ in 10 buildings (households, schools, offices, and meeting spaces).
- Estonian Pilot on Big Data Analytics: Equips 51 non-residential buildings (offices, schools, universities, and kindergartens) with low-cost sensors to measure the main parameters and pollutants in IAQ.
- Zagreb Pilot: Involves a cohort of 206 children, both with and without asthma, and collects clinical, demographic, socioeconomic, biological, as well as indoor and outdoor air pollution data.
- Filtration Pilot: Evaluates the efficiency and maintenance of air filtration systems in public buildings that have installed ventilation and air conditioning systems.

Campaigns:

- Sevilla Measurement Campaign: Campaign assesses indoor air pollutants and ventilation habits in schools, hospitals, and public transport, focusing on vulnerable populations.
- Vilnius Measurement Campaign: Investigates the impact of vehicular pollution on IAQ in schools.
- Evaluation of Low-Cost Sensors: Assesses the performance of consumer-grade sensors.
- Awareness Campaigns: Aims to increase environmental awareness to improve IAQ.

Main activities undertaken within pilots and campaigns:

- Data infrastructure implementation: Establishing systems for data collection, storage, and sharing, including the use of a central database for all pilots and campaigns.



- Sensor deployment and monitoring: Installing and maintaining air quality sensors in various locations and collecting data on a range of pollutants.
- IAQ monitoring, including biological and chemical characterisation of pollutants.
- Community engagement: Conducting workshops, webinars, and surveys to raise awareness and promote behavioural change related to IAQ.
- Data analysis: Analysing collected data to identify sources of pollution, assess the effectiveness of interventions, and understand the impact of IAQ on health.
- Development of recommendations: Formulating strategies for improving IAQ based on the project's findings.

Initial results from pilots and campaigns:

- Data Quality and Infrastructure: The results from the pilots conducted in Ferrara and Estonia emphasise the importance of a strong data infrastructure for monitoring IAQ. These pilots demonstrate the critical role of interoperability in maintaining data quality. Furthermore, the evaluation of the Low-Cost Sensorics campaign highlights the necessity of accurately calibrating and validating these sensors to ensure the reliability of the data.
- Source Apportionment: The Vilnius Measurement Campaign demonstrates that vehicular pollution is a major contributor to air pollution near schools, highlighting the need for effective strategies in school location planning and traffic management. Additionally, textile fibres have been identified as a significant source of indoor microplastics, underscoring the importance of material selection in indoor environments.
- Filtration Effectiveness: The Filtration Pilot found that the use of room-based air purifiers did not consistently reduce particulate matter (PM₁₀, PM_{2.5}) levels, raising questions about the effectiveness of those filtration systems. This suggests that local air filtration systems should be integrated into a comprehensive IAQ strategy, considering factors such as proper ventilation and source control.
- Insufficient Knowledge: Awareness campaigns reveal significant gaps in indoor air quality knowledge and behaviours among various demographic groups, emphasizing



the need for tailored educational materials and community outreach to enhance awareness and foster proactive action.

Based on the findings from pilots and campaigns, the following actions are recommended to improve indoor air quality in households, workplaces, schools, and other buildings:

- Promote a comprehensive approach to indoor air management that considers all factors:
 - Source Control: Identify and reduce indoor pollutant sources by selecting low-emission materials and cleaning products, maintaining appliances and ventilation, and adopting healthier habits like avoiding indoor smoking and using exhaust fans while cooking.
 - Local Extraction: Use localised exhaust systems like kitchen range hoods and bathroom fans to capture pollutants at their source.
 - Ventilation: Ensure proper ventilation to reduce indoor pollutants and moisture. Select the best ventilation strategy by integrating (natural, mechanical, or hybrid) according to building type, climate, outdoor pollution levels, occupancy, age of the building, and characteristics of the users.
 - Filtration and Air Cleaning: Use air cleaners and filters to remove pollutants from the air. Select the appropriate type based on the pollutants and room size, how the room is used, the type of activity carried out, the number of users, and regularly replace or clean the filters to maintain their efficiency.
- Implement educational programmes to raise awareness and empower individuals to take action.
- Engage both public and private sector building owners to create and enforce evidence-based indoor air quality standards in buildings.



2 Introduction

2.1 Pilots and Campaigns Overview

The EDIAQI project features four pilots and four campaigns.

- **Ferrara Pilot:** This pilot monitors indoor air quality in households, schools, offices, and meeting places in Ferrara, Italy. It deploys a network of sensors and passive samplers to measure parameters such as temperature, humidity, particulate matter (PM_{2.5}, PM₁₀), CO₂, CO, NO₂, O₃, TVOCs, and aromatics across 10 buildings. The pilot emphasises community engagement and behavioural change campaigns to improve occupant habits and awareness.
- **Estonian Pilot on Big Data Analytics:** This pilot instruments 51 municipal buildings (mainly on Tallinn and Tartu), including offices, schools, universities, and kindergartens, with Thinnect low-cost sensors measuring temperature, relative humidity, CO₂, O₃, and particulate matter (PM_{1.0}, PM_{2.5}, PM₁₀). Data are collected in a cloud-based platform linked with the central KNOW database. The pilot aims to enhance awareness and promote systemic change in understanding indoor climate parameters.
- **Zagreb Pilot:** This pilot involves a cohort of 206 children with and without asthma in Zagreb, Croatia. It includes the collection of clinical, demographic, socioeconomic, and biological data, as well as measurements of indoor and outdoor air pollution. The pilot links health data with environmental exposures for asthma management and research.
- **Filtration Pilot:** This pilot evaluates the efficiency and maintenance of selected air filtration systems in public buildings with installed ventilation and air conditioning systems. The study aims to establish pathways for IAQ improvement and will result in recommendations for efficient filters, optimal maintenance schedules, and filter replacement periods.
- **Evaluation of Low-Cost Sensorics:** This campaign focuses on the performance evaluation of multiple consumer-grade multi- and single-parameter sensors in detecting particulate matter (PM_{2.5}, PM₁₀), CO₂, NOX, TVOCs, temperature, and



relative humidity. The campaign aims to provide a robust foundation for suggesting the most suitable low-cost air quality monitors for long-term IAQ applications.

- **Measurement Campaign in Sevilla:** This campaign characterises indoor air pollutants and studies ventilation habits in schools, hospitals, residential areas, and public transport, particularly for vulnerable populations. The campaign aims to provide a detailed insight into the behaviour and variability of pollutants in urban indoor environments.
- **Measurement Campaign in Vilnius:** This campaign examines how vehicular pollution affects IAQ in schools. High-pollution schools utilise advanced aerosol measurement tools and low-cost sensors to analyse aerosol size distribution, ultrafine particles (UFP), and black carbon concentrations. The campaign also assesses microplastic levels from collected air samples.
- **Awareness Campaigns:** This campaign aims to detect knowledge gaps on IAQ and to raise environmental awareness and reduce outdoor and indoor air pollution. The campaign targets children and their families involved in pilot studies as well as a broader public from several EU countries and includes a questionnaire to assess participants' knowledge about health-related issues regarding IAQ.

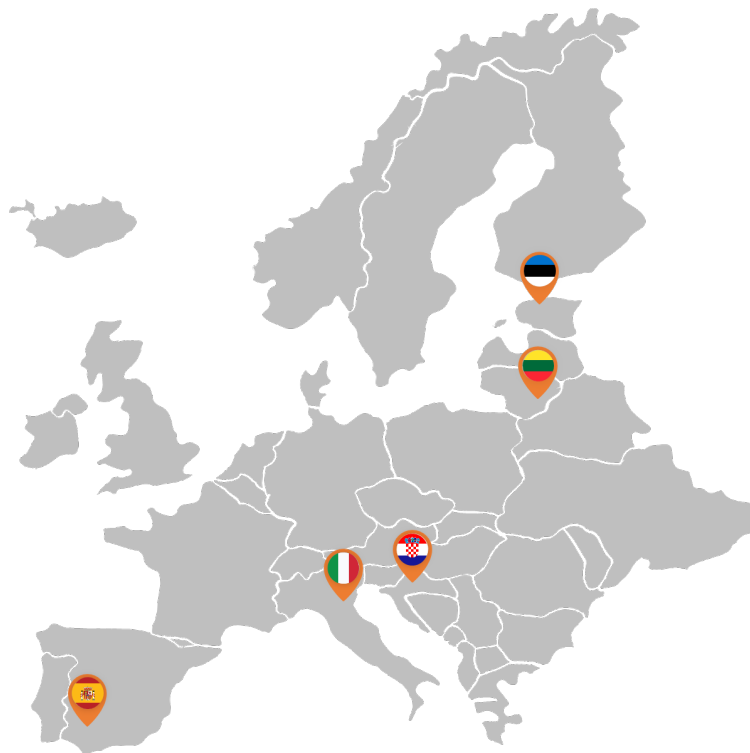


Figure 1 Locations of pilots and campaigns

2.2 Data collection

As part of the EDIAQI project, 67 pilot buildings are equipped with 170 IAQ monitoring stations that measure IAQ conditions in real time: temperature, relative humidity, CO₂, PM₁, PM_{2.5}, PM₁₀, and, depending on the sensor manufacturer, also CO, O₃, NO₂, and TVOCs.

Table 1 Number of pilot buildings and installed monitoring stations

Location	Number of buildings	Number of stations	Measurements
Ferrara, Italy	10	36	Real-time IAQ monitoring, chemical sampling of TVOCs and concentration of formaldehyde.
Estonia	51	107	Real-time IAQ, chemical sampling of TVOCs and concentration of formaldehyde. QR code-based occupant feedback on IAQ.
Vilnius, Lithuania	1	18	IAQ, chemical sampling of TVOCs and concentration of formaldehyde. QR code-based occupant feedback on IAQ. Aerosol particle number concentration and size distribution. Black carbon mass concentration measurements. Sampling of microplastics.
Seville, Spain	5	9	IAQ, chemical sampling of TVOCs and concentration of formaldehyde.

Monitoring stations are provided by three project partners: Lab Service Analytica (LAS), Thinnect (THIN), and Wings ICT Solutions (WINGS). Measured air quality parameters:

- LAS - T°, RH, PM_{2.5}, PM₁₀, CO₂, CO, NO₂, O₃, TVOC, Aromatics (10/50)
- THIN - T°, RH, CO₂, PM₁, PM_{2.5}, PM₁₀, O₃, TVOC
- WINGS - T°, RH, CO₂, PM₁, PM_{2.5}, PM₁₀

Activities conducted under task 4.2 involved pilots and campaigns focused on data collection. The analyses of the collected data are linked with other work packages:

- The performance of these low-cost sensors is evaluated under the campaign “Evaluation of Low-Cost Sensorics,” which is closely linked with WP3 (Science).
- Health data were collected in the Zagreb pilot, which involved 206 children with asthma or allergies, as well as non-allergic control subjects. The Zagreb pilot is linked to WP5 (Tox and Health). Chemical and biological IAQ data are related to WP3 (Science).



- The assessment of public awareness about the health impacts of indoor air pollution is part of an awareness campaign linked to WP5 (Tox and Health).

IAQ data collected in pilots and campaigns is stored in a central database, enabling data troubleshooting, comparison, and analysis across pilots and campaigns. Data can be accessed through the EDIAQI dashboard.

[Visit the EDIAQI Dashboard](#)

The central database also enables future research projects to utilise the collected information.

Analyses and comparisons of IAQ from pilots and campaigns will be published in research papers. The current deliverable provides an overview of how the pilots and campaigns achieved their targets. Each pilot and campaign has a single paragraph with sub-paragraphs detailing their specific deliverables.



3 P1 – Ferrara Pilot

Ferrara Pilot focuses on four building categories—households, high schools, offices, and meeting places—and ten indoor scenarios tied to daily activities, such as living rooms, laboratories, classrooms, and fitness areas. The initiative encourages community engagement through behaviour change campaigns to collect data and improve occupant habits. By dynamically gathering well-being perceptions and utilising low-cost indoor multisensory devices and unattended samplers, the project aims to provide comprehensive data on indoor air pollutants and deliver daily updates to participants on their environments, thereby fostering continuous improvement in living, studying, and recreational conditions.

Pilot deliverables:

P1.1 Implementation of data infrastructure based on geo-ICT and geomatics standards.

P1.2 Deployment of an existing network of ambient air quality monitoring.

P1.3 Workshops/Communication actions to promote awareness.

P1.4 Report on behavioural change campaigns.

3.1 Implementation of data infrastructure based on geo-ICT and geomatics standards

In the Ferrara pilot, the data has been fully implemented based on the guidelines defined in Deliverables D4.3 and D4.7 (Framework and Standards for Data Interoperability).

An instance of the FROST Server open-source solution has been deployed and configured at Lab Service Analytica (LAS) premises for managing dynamic IAQ data. Dynamic data are being collected from both NetPID active monitoring stations and Radiello© passive samplers:





Figure 2 Radiello passive sampler (left) and NetPID station (right)

As explained in D4.3 and D4.7, the FROST server is a reference implementation of the SensorThings API standard protocol (STA) published by the Open Geospatial Consortium (OGC). STA is a vendor-neutral protocol RESTful interface that allows IoT data to be interoperable at both semantic and syntactic levels.

An STA endpoint can be requested by different software clients or browsed directly using common web browsers: the following image is a screenshot of one response from the FROST instance deployed at Lab Service Analytica (LAS).

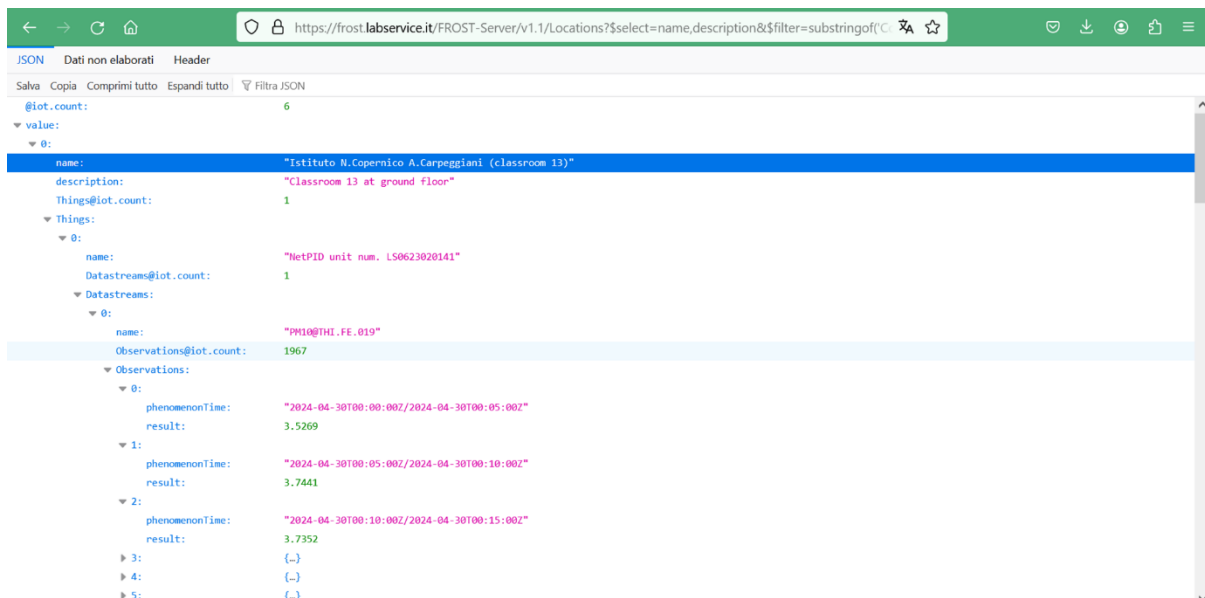


Figure 3 FROST Server response (via SensorThings API standard protocol)

The location of each “thing” (Radiello© samplers and NetPID stations) has been registered in the FROST server with exact coordinates: this enables GIS (Geographic Information System) software solutions to access information about IAQ data in Ferrara through a map



by interoperating with the FROST server via SensorThings API standard protocol (defined by Open Geospatial Consortium).

Moreover, static properties about monitoring stations have also been configured (on Deda. Next geographical server) to be accessible via ISO19128 (WMS) and ISO19142 (WFS) standard protocols.

In the following figure, for instance, a screenshot from QGIS open-source GIS software is presented to showcase the properties of one NetPID station installed at Istituto Aleotti high school:

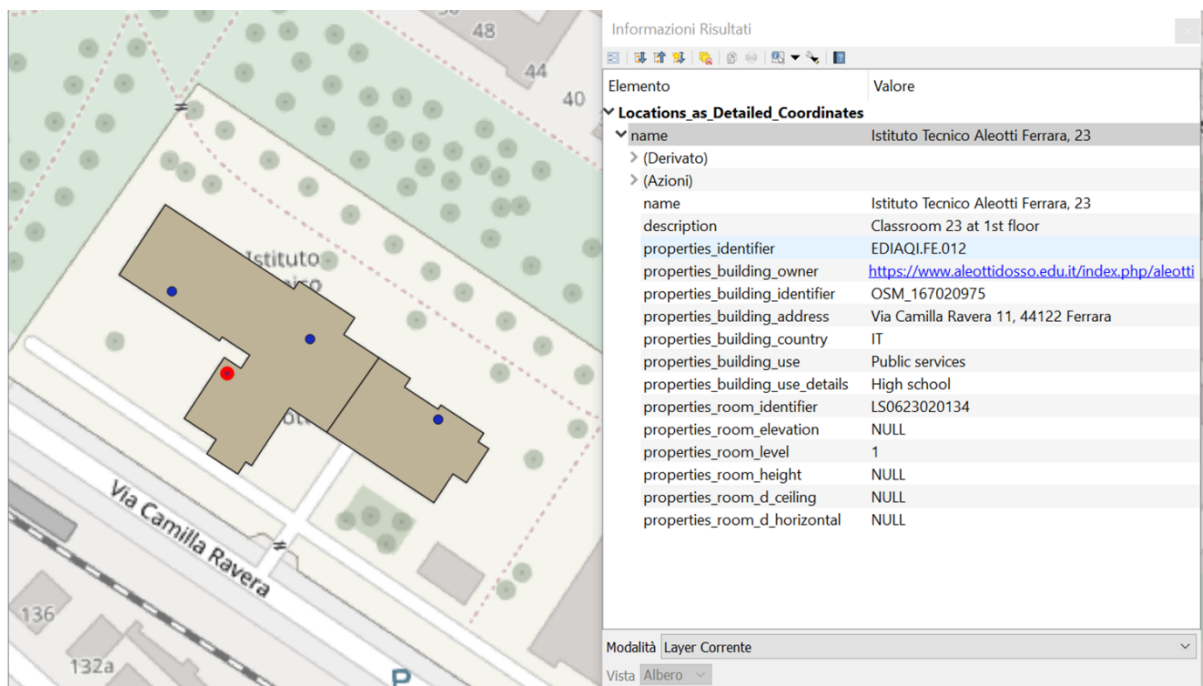


Figure 4 QGIS desktop access to static properties of NetPID stations

The image below depicts the overall data infrastructure implemented:

on the left, the proprietary stack used by Lab Service Analytica (LAS), with NetPID monitoring stations on top and raw measurements stored in cloud-based platform, with proprietary (non-standard) API providing access to data.

In the middle, there is the middleware layer of standard components implementing the SensorThings API standard, providing access to data in a standard/interoperable way

on the right, we see examples of user interfaces (web dashboard and GIS desktop client) enabled to access dynamic data and timeseries by interacting via standard protocols (STA and ISO/OGC WMS and WFS).



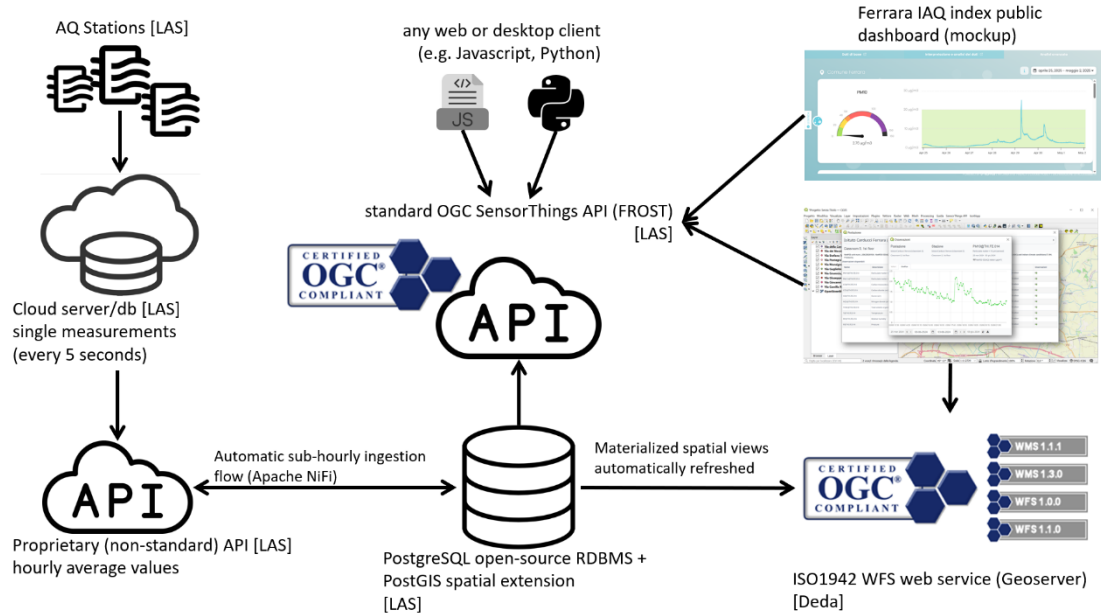


Figure 5 Data infrastructure based on geo-ICT and geomatic standards

3.2 Deployment of an existing network of ambient air quality monitoring



Figure 6 Location of buildings monitored in the Ferrara Pilot

In detail, in Ferrara, we focused on 10 buildings, divided into the 4 categories proportionally and to be able to lay the groundwork for subsequent studies to compare places with similar characteristics in terms of activity and type of occupants (excluding restaurant room).



The location of the buildings was not only based on the availability of the stakeholders preliminarily identified together with the Municipality of Ferrara but also considering the distance from the smart ambient air quality monitoring network points owned by the Municipality of Ferrara, but produced, installed, and currently maintained by Lab Service Analytica (LAS). So, to enable planned research activities on the role of outdoor air quality in indoor air pollution.

A letter of intent about project scopes/management of units and/or a free loan agreement has been established for each pilot building. The following is the list of selected buildings.

Table 2 Pilot buildings in Ferrara

Nr.	Abbreviation	Category	Units	Installation (sensors)
1	Casa Verri	Home	1	3-7-2023
2	AMI	Offices	3	4-7-2023
3	Uffici Ambiente	Offices	6	24-1-2024
4	Maverna	Offices	4	4-7-2023
5	Capatoast	Entertainment	1	5-7-2023
6	CUS Ferrara	Entertainment	5	28-11-2023
7	Ist. Carducci	School	5	04/10/2023
8	Ist. Copernico	School	6	28-11-2023
9	Ist. Tec. Sup. TEC	School	4	6-10-2023
10	Lo Piccolo - PG	Home	1	29-3-2024

Under the current monitoring programme, a total of 36 air quality measurement units were installed divided as follows.



Table 3 Measured air quality parameters in Ferrara

Category	Abbreviation	Notes	T°, RH	PM	CO ₂	CO	NO ₂	O ₃	TVOCs	Aromatics
Homes	Casa Verri	Living room	X	X	X	X	X	X	X	
Homes	Lo Piccolo - PG	Living room	X	X	X	X	X	X	X	X
Offices	AMI	Office of Marzia	X	X	X	X	X	X	X	
Offices	AMI	Office of Rossella	X	X	X	X	X	X	X	
Offices	AMI	Office of Ilaria	X	X	X	X	X	X	X	
Offices	Maverna	Office 19 of Tommaso & Claudia	X	X	X	X	X	X	X	
Offices	Maverna	Office 21/A of Maddalena	X	X	X	X	X	X	X	
Offices	Maverna	Office 6 of Franco	X	X	X	X	X	X	X	
Offices	Maverna	Office 12 of Giuseppe & Marina	X	X	X	X	X	X	X	
Offices	Uffici Ambiente	URP - Reception	X	X	X	X	X	X	X	
Offices	Uffici Ambiente	URP - Waiting zone	X	X	X	X	X	X	X	
Offices	Uffici Ambiente	Office - Trevisani e Cilio	X	X	X	X	X	X	X	
Offices	Uffici Ambiente	Office - Braghetta & Bosi	X	X	X	X	X	X	X	X
Offices	Uffici Ambiente	Office - Contiero	X	X	X	X	X	X	X	X
Offices	Uffici Ambiente	Office - Piras & Panizza	X	X	X	X	X	X	X	X
Entertainment	Capatoast	Recreation area	X	X	X	X	X	X	X	
Entertainment	CUS Ferrara	Fitness Gym	X	X	X	X	X	X	X	
Entertainment	CUS Ferrara	Cardio Gym	X	X	X	X	X	X	X	
Entertainment	CUS Ferrara	Fitness Gym 2	X	X	X	X	X	X	X	
Entertainment	CUS Ferrara	Reception	X	X	X	X	X	X	X	
Entertainment	CUS Ferrara	Spinning Gym	X	X	X	X	X	X	X	
Schools	Ist. Aleotti e ITS TEC	Classroom 1 C.A.T	X	X	X	X	X	X	X	
Schools	Ist. Aleotti e ITS TEC	Leisure time	X	X	X	X	X	X	X	
Schools	Ist. Aleotti e ITS TEC	Classroom 23	X	X	X	X	X	X	X	
Schools	Ist. Aleotti e ITS TEC	Informatic Lab. INFO3	X	X	X	X	X	X	X	
Schools	Ist. Carducci	Classroom 5 - I° Floor	X	X	X	X	X	X	X	
Schools	Ist. Carducci	Classroom T2 - G. Floor	X	X	X	X	X	X	X	
Schools	Ist. Carducci	Classroom 2 - I° Floor	X	X	X	X	X	X	X	
Schools	Ist. Carducci	Classroom 18 - II° Floor	X	X	X	X	X	X	X	
Schools	Ist. Carducci	Classroom 21 - II° Floor	X	X	X	X	X	X	X	
Schools	Ist. Copernico	Laboratory	X	X	X	X	X	X	X	
Schools	Ist. Copernico	Laboratory	X	X	X	X	X	X	X	
Schools	Ist. Copernico	Laboratory of technical drawing	X	X	X	X	X	X	X	
Schools	Ist. Copernico	Leisure time	X	X	X	X	X	X	X	
Schools	Ist. Copernico	Classroom 2	X	X	X	X	X	X	X	
Schools	Ist. Copernico	Laboratory of Chemistry and Microbiology	X	X	X	X	X	X	X	



Main parameters evaluated (also in parallel outdoor environments) are:

- $PM_{2.5}$ (Fine Particulate Matter) - Fine dust with a diameter of less than 2.5 micrometres. This is particularly harmful to health as they can penetrate deep into lungs and even in bloodstream.
- CO (Carbon Monoxide) - Colourless and odourless gas that is highly toxic. It is formed mainly from the incomplete combustion of fuels such as wood, coal, or natural gas.
- CO_2 (Carbon Dioxide) - Gas produced by human respiration and sources such as combustion and industrial processes. High levels indicate inadequate ventilation.
- NO_2 (Nitrogen Dioxide) - Toxic gas produced primarily by fuel combustion (e.g. vehicular traffic, heating). It can irritate the respiratory tract and contribute to O_3 secondary formation.
- O_3 (Ozone) - Gas formed naturally in the atmosphere but can also be produced by chemical reactions between pollutants (VOC and NO_2) in the presence of sunlight. At ground level, it is a pollutant that irritates the respiratory tract.
- TVOCs (Total Volatile Organic Compounds) - Total volatile organic compounds in the air. These compounds include substances such as benzene, formaldehyde, and other chemical solvents, often released from building materials, furniture, cleaning products, and combustion.

In accordance with the laboratory activities under the project, UMOL carried out seasonal passive sampling campaigns (10-15 days each) to go in and characterise and quantify the presence of the three categories of VOCs:

- Aliphatics are present in many industrial and consumer products, such as solvents, fuels, and plasticizers. These compounds can contribute to air pollution, but fortunately, their presence is not particularly harmful to human health or the environment.
- Aromatics for example benzene, toluene, are commonly used as solvents, in paints, fuels, and in various industrial processes. Many of these compounds are hazardous to the environment, and their presence can cause harm to human health.



- Chlorinated are mainly used as industrial solvents, detergents, disinfectants, etc. Although they are useful in various fields, many chlorinated VOCs are considered hazardous to human health and the environment because they can be carcinogenic.

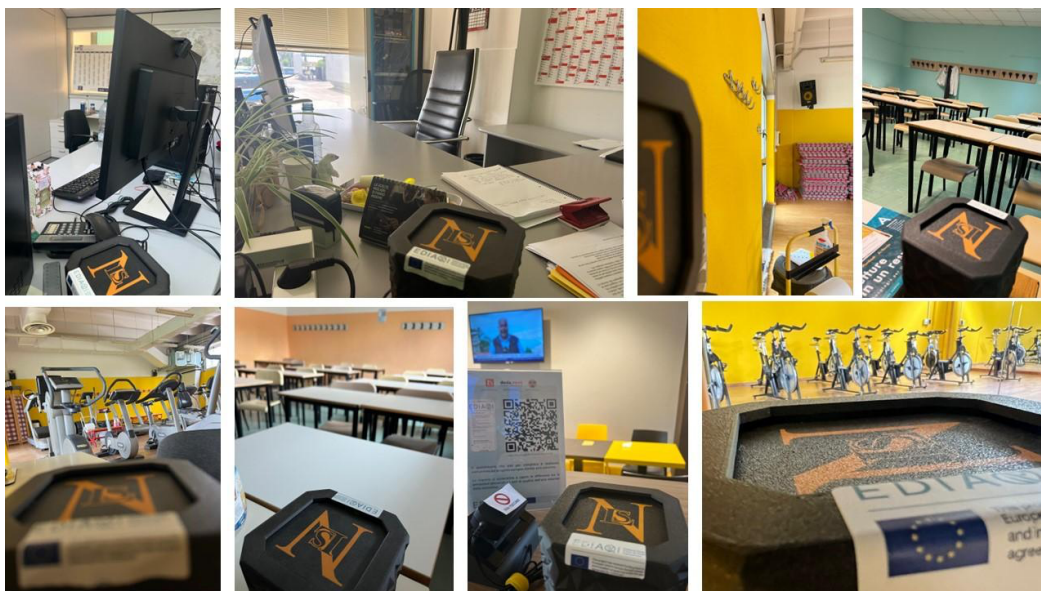


Figure 7 Installation of Netpid™ EDIAQI monitoring unit in Ferrara

3.3 Workshops/communication activities to promote awareness

To raise awareness among those involved and within the pilot buildings, we launched a range of initiatives designed to educate and engage participants on these highly relevant and important issues. Our commitment included both educational activities and opportunities for co-design and public engagement.

We also involved an external collaborator within the EDIAQI project in helping strengthen direct contact with the pilot-building representatives and support us in the operational activities of WP4, specifically those outlined in Task 4.2. These activities included:

- In October 2023, the organisation of a workshop focused on the topics of air quality, health, and the environment. This was a dynamic and participatory event, open to citizen involvement, aimed at sharing experiences, research, and urban innovation.
 - [Workshop Progetto EDIAQI](#)
- In early 2025, the delivery of concise reports on IAQ, one for each of the 10 pilot buildings in Ferrara, to make monitoring results easily accessible and user-friendly.



- In March 2025, a first online webinar was organised to raise awareness among building representatives and school staff about the causes and health impacts of indoor pollution.
 - [Webinar Recording: PILOT WEBINAR - Qualità Aria Indoor, Cause ed Effetti](#)
- In April and May 2025, 13 representatives of pilot buildings (teachers, students, civil servants, researchers) were involved in the UX co-design process for the IAQ Index dashboard, taking part in two in-person meetings in Ferrara. The main objective of the sessions was to explore how to visualise IAQ data effectively and to generate innovative design concepts. The first session laid the foundations through discussion and analysis of data visualisation examples, while the second session focused on developing concrete ideas and graphic prototypes.
- In late April 2025, the organisation of an [in-person seminar](#) at the Auditorium of the Carducci Institute in Ferrara. The seminar focused on IAQ and the sharing of best practices to ensure healthy indoor environments.
 - [Empowering the Next Generation to Breathe Better](#)
- Among the planned activities, there will be the organisation of a second online webinar (October 2025) followed by the participation in ECOMONDO Fair 2025, a leading environmental event, together with some representatives of schools to present the results and experiences gained within the EDIAQI project.
 - [ECOMONDO Fair 2025](#)

To ensure ongoing and more direct communication with the pilot building representatives, we created a dedicated WhatsApp group. This platform allowed us to maintain active engagement beyond official events. Through it, we periodically shared quizzes, invitations to webinars and events, and ideas for further exploration, helping foster continuous participation and involvement from the network of representatives.

3.4 Report on behavioural change campaigns

Behaviour change campaigns are still ongoing and will find direct applications between 2025 and 2026 following the involvement of residents of the various pilot buildings including through direct access to customised dashboards showing air quality values in near real-time.



Behavioural change campaigns are currently being conducted to collect information on air quality perception and awareness regarding the topic. Surveys aimed at understanding the current knowledge of indoor air quality and the perceived state of well-being or comfort within the premises, regardless of whether indoor air pollutants exceed recommended thresholds.

Results of the campaigns conducted so far in Ferrara can be found by consulting deliverable D5.5.



4 P2 – Estonian Pilot on Big Data Analytics

The Estonian pilot focuses on various municipal buildings, including administrative offices, schools, and universities, by installing sensors to monitor IAQ. Its main goal is to enhance awareness of indoor climate parameters by integrating AI and Big Data Analytics for data analysis. This initiative aims to promote systemic change in understanding and behaviour through better instrumentation and by analysing the experiences of building users.

Pilot deliverables:

P2.1 At least 50 municipal buildings instrumented with sensors and connected to the platform.

P2.2 Working cloud solution for data collection.

P2.3 Communication actions to building users.

4.1 At least 50 municipal buildings instrumented with sensors and connected to the platform.

A total of 50 non-residential buildings equipped with 106 air quality measuring devices are connected to a data platform in the Estonian pilot programme. The buildings include: 15 office buildings, 13 schools, 12 university buildings, and 10 kindergartens.

Table 4 Pilot buildings in Estonia

	Building name	Building type	No. of devices
City of Tartu	Tartu Forseliuse Kool	school	2
	Tartu Mart Reiniku Kool	school	2
	Tartu Lasteaed Krõll	kindergarten	2
	Tartu Lasteaed Poku	kindergarten	2
	Tartu Lasteaed Rukkilill	kindergarten	2
	Tartu Lasteaed Mõmmik	kindergarten	2
	Tartu Lasteaed Lepatriinu	kindergarten	2
	Tartu Lasteaed Pääsupesa	kindergarten	2
City of Tallinn	Pirita Linnaosa Valitsus	office	2
	Tallinna Linnavalitsus	office	2
	Tallinna Linnavaraamet	office	2
	Tallinna Linnavolikogu	office	2
	Tallinna Sotsiaal- ja Tervishoiuamet	office	2
	Kesklinna koolide asenduspinnad	school	2
	Nõmme Linnaosa Valitsus	office	2
	Põhja-Tallinna Linnaosa Valitsus	office	2
	Lasnamäe Linnaosa Valitsus	office	2



	Tallinna Linnaplaneerimise amet	office	2
	Kadrioru Saksa Gümnaasium	school	2
	Kadrioru Saksa Gümnaasium	school	2
	Lasnamäe Gümnaasium	school	2
	Tallinna 32. Keskkool	school	2
	Tallinna Lilleküla Gümnaasium	school	2
	Tallinna Kihnu Lasteaed	kindergarten	2
	Tallinna Kiisa Lasteaed	kindergarten	2
	Tallinna Muinasjutu Lasteaed	kindergarten	2
	Tallinna Männikäbi Lasteaed	kindergarten	2
	Tallinna Majanduskool	school	3
Manor schoolhouses	Ruila Põhikool	school	2
	Vääna Mõisakool	school	2
	Laupa Põhikool	school	2
	Vasalemma Põhikool	school	3
Tallinn University of Technology	Ehituse Mäemaja	university	3
	Majandusteaduskonna õppehoone	university	3
	Raamatukogu	university	2
	Energeetikamaja	university	2
	Õppehoone U01	university	2
	Õppehoone U02	university	2
	Õppehoone U03	university	2
	Õppehoone U04	university	2
	Õppehoone U05	university	3
	Õppehoone U06	university	3
	Tudengimaja	university	2
	Infotehnoloogiateaduskonna õppehoone	university	2
Private office buildings	Nortal Tartu	office	1
	Thinnect	office	1
	Bolt	office	3
	Salv	office	3
	Fund Ehitus	office	3
	Erinevate Tubade Klubi	office	1

All buildings are equipped with Thinnect's low-cost sensors that measure temperature, relative humidity, CO₂, PM_{1.0}, PM_{2.5}, PM₁₀, O₃, and TVOC levels.





Figure 8 Low-cost air quality sensors used in Estonian pilot buildings

Data from the Estonian pilot is collected and analysed in a local database and the central KNOW database (Task 4.1). The local data management system utilises a cloud-based database, analysis algorithms, and a user interface.

4.2 Working cloud solution for data collection.

Air quality and thermal comfort (temperature and relative humidity) parameters are measured using low-cost sensors, sent to a cloud-based database, analysed, and visualised in the user interface.

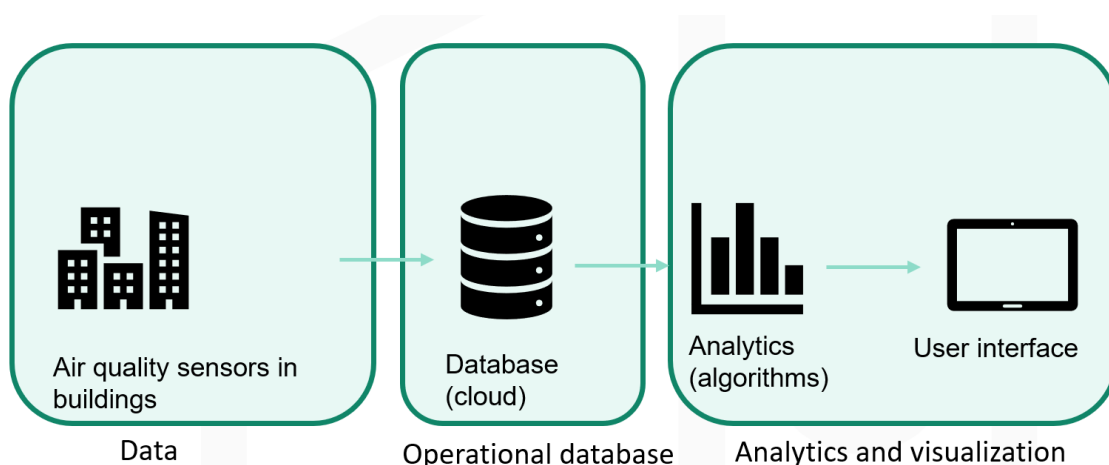


Figure 9 Concept of collecting and analysing data in the Estonian pilot.

There are two types of automatic assessments for pollutants:



This project has received funding from the European Union's Horizon Europe Framework Programme under grant agreement N° 101057497.

1. **Classification:** Weekly, monthly, and yearly evaluations will categorise pollutants into four Indoor Climate Classes (ICC). This will be conducted over a flexible period, considering factors such as data availability, occupancy times, and allowed deviations.

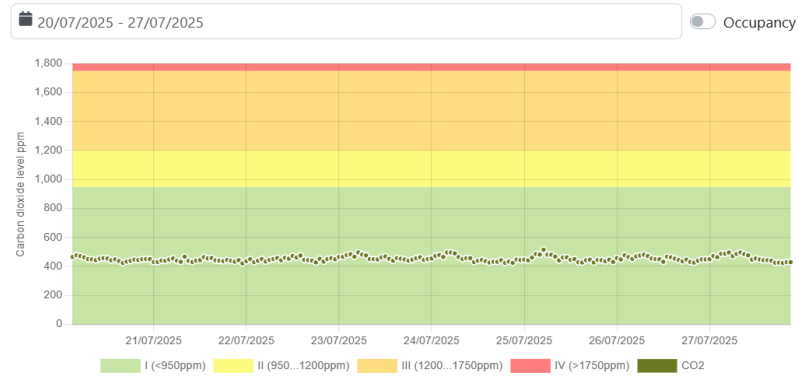
Colour codes:

ICC I		High demands on indoor climate quality (buildings with special requirements).
ICC II		Normal demands on indoor climate quality (new and renovated buildings).
ICC III		Moderate demands on indoor climate quality (existing buildings).
ICC IV		Allowed only during limited times of the year.

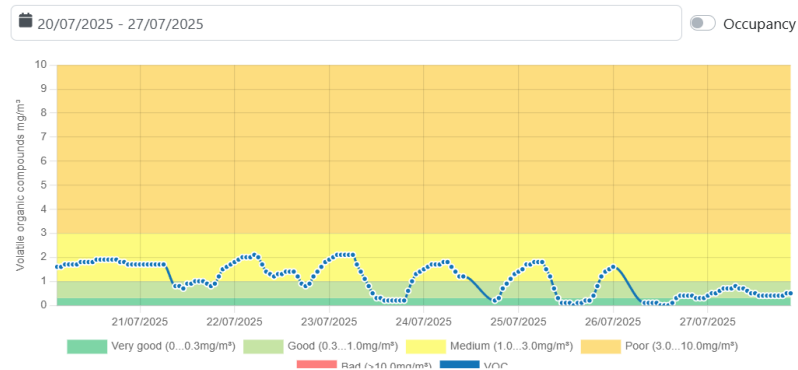
2. **Real-time feedback:** This involves short-term compliance checks against specific limits. It will compare the most recent values to the World Health Organization's daily guidelines value recommendations, providing immediate feedback on pollutant levels.



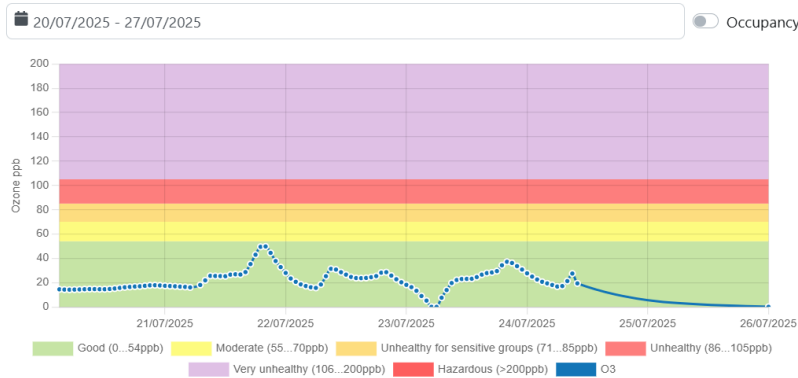
CO2 level



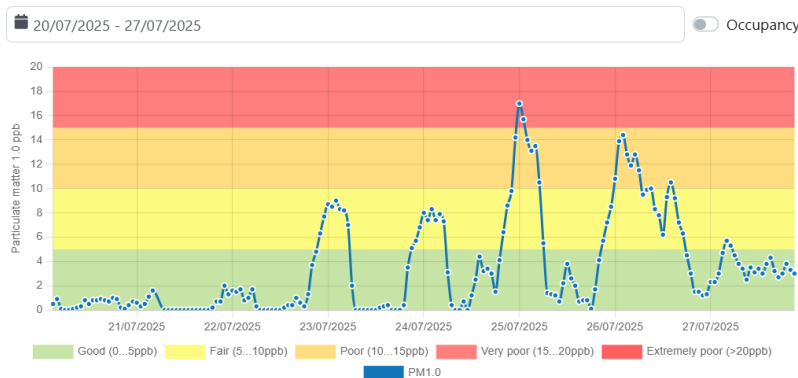
Volatile organic compounds



Ozone



Particulate matter 1.0



This project has received funding from the European Union's Horizon Europe Framework Programme under grant agreement N° 101057497.

Figure 10 Data visualisation and indoor climate classes in the user interface.

4.3 Communication actions to building users.

Building users can provide feedback on their satisfaction with the indoor climate through QR code-based posters.

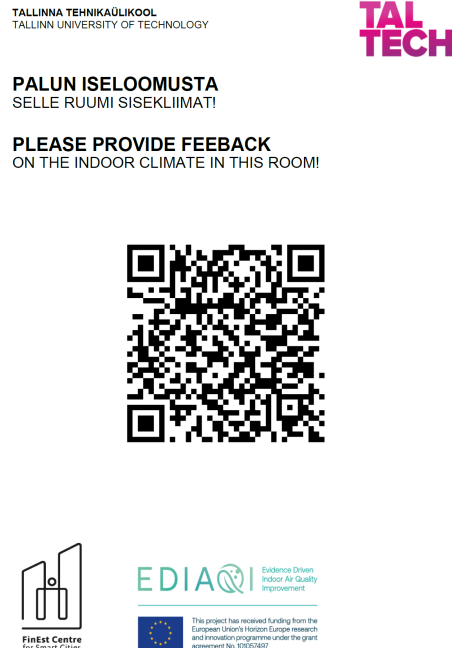


Figure 11 Feedback collection poster (this is a test zone poster, so please feel free to try it out).

After scanning the QR code, users are asked to evaluate indoor air quality on a four-point scale and the thermal comfort of the room on a three-point scale.



This project has received funding from the European Union's Horizon Europe Framework Programme under grant agreement N° 101057497.

The figure displays two mobile application screens for indoor climate feedback. Both screens show the 'TAL TECH' logo and a language selector set to 'English'. The left screen asks 'How is the air quality?' and provides four radio button options with corresponding smiley face icons: 'Fresh and nice' (green), 'Moderate, slightly disturbing odours' (yellow), 'Bad, disturbing odours' (orange), and 'Intolerable odours' (red). The right screen asks 'How is the temperature in the room?' and provides three radio button options: 'Too warm' (red), 'Comfortable' (green), and 'Too cool' (blue). Both screens feature a blue 'Submit' button at the bottom.

Figure 12 Evaluation questions for indoor climate satisfaction.

Building owners or facility managers can generate automated reports from the user interface about their building's indoor climate quality over weekly, monthly, and yearly timescales. The report employs a traffic light colour system to indicate the levels of measured pollutants in each room equipped with an indoor climate sensor. Rooms marked in green are considered safe, those marked in yellow are satisfactory, and rooms marked in red require attention from the building owner or facility manager.



Siseõhu kvaliteedi raport: [Hoone nimi]

[Aadress]

Raporti kuupäev:

[dd.mm.202x]

LÜHIKOKKUVÕTE

Ülevaade. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Suspendisse nec augue massa. Quisque eu mollis justo. Ut molestie metus a vehicula semper. Vivamus dolor lacus, vehicula ac finibus semper, congue nec turpis. Donec pretium est turpis, vel rutrum nisi efficitur sagittis.

Soovitused. Donec faucibus egestas eros, porttitor egestas diam. In dolor turpis, condimentum ac mi at, mattis mattis urna. Nunc velit est, varius nec mi nec, gravida mattis lectus.

Võtmenäitajad

Raport on koostatud kolme peamise parameetri alusel: temperatuur, CO₂, PM_{2,5}

Lisaks on mõõdetud PM₁₀, NO₂, O₃, TVOC, mille mõõdetulemused on kättesaadavad kasutajaliidesest

Tulemuste tabeli värvikoodide selgitus

sisekliima klass I		Kõrged nõudmised sisekliima kvaliteedile (erinõuetega hooned).
sisekliima klass II		Tavapärased nõudmised sisekliima kvaliteedile (uued ja renoveeritavad hooned).
sisekliima klass III		Mõõdukad nõudmised sisekliima kvaliteedile (olemasolevad hooned).
sisekliima klass IV		Lubatud ainult piiratud ajal aastast.

Ruumide andmetes kuvatud arvuline väärtus näitab vastava parameetri iseloomulikku väärtust.

Sisekliima on korras, kui tulemus on esimeses või teises klassis (lahter on roheline).

Nädal

Sisekliima parameeter	Soovituslik vahemik	Ruumi number		
Temperatuur (°C)	Talvel 20-24°C / suvel 23-26°C			
CO ₂ (ppm)	400-1200			
PM _{2,5} (µg/m³)	<25 µg/m³			

<https://ediaqi.eu/>



This project has received funding from the European Union's Horizon Europe research and innovation programme under the grant agreement No. 101057497

Figure 13 An automated indoor climate report.



This project has received funding from the European Union's Horizon Europe Framework Programme under grant agreement N° 101057497.

5 P3 – Zagreb Pilot

The pilot will be conducted in Zagreb with the SCH2021 cohort (section 1.2.1.4) consisting of more than 200 participants, children aged 6-18 years with a physician diagnosed asthma or related respiratory diseases, as well as a control group of non-asthmatic children, matching in age and sex, from the Zagreb region, Croatia. Participants were recruited at the Srebrnjak Children's Hospital (SCH). Children's bedrooms were equipped with pollutant samplers and low-cost sensors for chemical IAP characterisation while dust was collected for chemical and microbiome composition analysis. WINGS provided air quality monitoring sensors for 3-day campaigns, which were conducted by ASC. Chemical characterisation of IAP in households was carried out by IMROH while microbiome dust analysis was performed by ANT.

Participants have regular follow-ups at the SCH Clinic (every 3-6 months) for asthma management. Biological samples were collected for clinical biomarker analysis, including inflammation and gene expression profiles, as well as blood lymphocytes and buccal cells. Participants use mobile spirometers connected to smartphones and complete the ISAAC and other questionnaires.

Pilot deliverables:

P3.1: Report on clinical, demographic, socioeconomic and biological data of 200 children with asthma.

P3.2: Report on air pollution data indoors and outdoors.

P3.3: Report on microbiome data in dust samples.

P3.4: Report on genomic instability data in children related to IAQ.

5.1 Report on clinical, demographic, socioeconomic and biological data of 200 children with asthma.

The Zagreb cohort was fully recruited and visited to conduct air quality measurements. This table summarises demographic and clinical characteristics of 206 participants, divided into two groups based on asthma status:

- Level 0 (no asthma, $n = 128$) and Level 1 (asthma, $n = 78$).
- P-values indicate the significance of group differences for each variable.



- Age [y] (mean (SD)): Children with asthma were significantly older (mean age 11.86 ± 3.78 years) compared to those without asthma (9.09 ± 3.50 years); $p < 0.001$.
- Gender (M=1; F=2) (%): Males were more prevalent in the asthma group (70.5%) than in the non-asthma group (47.2%), indicating a significant gender difference between groups; $p = 0.004$.

Allergic Rhinitis (yes=1, no=0) (%):

- Significantly more common in the asthma group (91.0%) than in the non-asthma group (42.5%); $p < 0.001$.

Atopic Dermatitis (yes=1, active now=2, no=0) (%):

- No statistically significant difference between groups; $p = 0.265$.
- Most children in both groups did not currently have atopic dermatitis.

Atopy (%):

- Defined as a positive allergic predisposition (Y=yes, N=no)
- Much more prevalent in the asthma group (84.6%) compared to the non-asthma group (60.9%); $p = 0.001$.

Table 5 Demographic and clinical characteristics of EDIAQI Zagreb cohort

	n	Stratified by Asthma		p	test
		level 0	1		
Age [y] (mean (SD))		128	78		
		9.09 (3.50)	11.86 (3.78)	<0.001	
Gender (M=1; F=2) (%)		60 (47.2)	55 (70.5)	0.004	
		2	23 (29.5)		
		8	0 (0.0)		
BMI percentile (underweight=1, normal=2, overweight=3, obese=4) (%)		5 (5.9)	1 (1.8)	0.109	
		2	35 (62.5)		
		3	9 (16.1)		
		4	11 (19.6)		
Allergic rhinitis (yes=1, no=0) (%)		69 (57.5)	7 (9.1)	<0.001	
		1	70 (90.9)		
Atopic dermatitis (yes=1, active now=2, no=0) (%)		101 (84.2)	61 (79.2)	0.265	
		1	14 (18.2)		
		2	2 (2.6)		
Atopy (%)		20 (15.6)	8 (10.3)	0.001	
		N	4 (5.1)		
		Y	66 (84.6)		

5.2 Report on air pollution data indoors and outdoors.

Zagreb Pilot IAQ measurements were based on the SCH2021 cohort. IAQ measurements were carried out in households of participants from the City of Zagreb and its surroundings (Zagreb County) who consent for that part of the investigation.



Out of 206 study participants recruited at SCH, air quality measurements were conducted in a total of 152 households. The lower number of households is due to participants either not consenting to the measurements or multiple participants coming from the same household. As a first step, all participants' parents who consented to this part of the study completed a questionnaire on their habits and household characteristics.

Campaign design, including applied sampling and measuring techniques, duration of sampling and measurements per household, as well as the type of measurement (indoor/outdoor) are described in *Deliverable D3.1 Indoor Air Pollution Observation Toolkit* and *Deliverable D3.2 Guidelines for Pilot City Labs to setup indoor pollutant monitoring stations*.

Measurements of selected gaseous pollutants and meteorological parameters (CO, CO₂, NO₂, O₃, TVOC, PM₁₀, PM_{2.5}, PM₁, air temperature, relative humidity, pressure) were carried out indoors and outdoors by sensor systems during 3-day campaigns.

Household dust was sampled for microbiome determination (described in P3.3: Report on microbiome data in dust samples).

For methodology comparison (WP3 Science), in addition to VOC samples collected by active sampling and analysed by IMROH, 20 VOC samples were collected using Radiello® passive samplers and analysed by UMOL. Furthermore, microplastics samples were collected and analysed in parallel by IMROH and FTMC by different analytical techniques.

IAP characterisation consisted of the quantitative determination of pollutants listed in Table 6.

Table 6 The list of pollutants determined in Zagreb pilot households

Pollutant	Unit	Sampling duration	Type
PM ₁	µg m ⁻³	7 days	indoor, outdoor
PAHs in PM ₁ Fluoranthene, Pyrene, Benzo(a)anthracene, Chrysene, Benzo(j)fluoranthene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, Dibenzo(ah)anthracene, Benzo(ghi)perylene, Indeno(1,2,3-cd)pyrene	ng m ⁻³	7 days	indoor, outdoor
PAHs in dust samples Fluoranthene, Pyrene, Benzo(a)anthracene, Chrysene, Benzo(j)fluoranthene,	ng g ⁻¹		indoor



Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, Dibenzo(ah)anthracene, Benzo(ghi)perylene, Indeno(1,2,3-cd)pyrene			
VOCs 2-methylpentane, Methylene chloride, Methylcyclopentane, Chloroform, 2-methylhexane, Cyclohexane, Benzene, Heptane, Trichloroethylene, Methylcyclohexane, Toluene, Tetrachlorethylene, Ethylbenzene, m-Xylene, p-Xylene, o-Xylene, Styrene, 1,3,5-Trimethylbenzene, 1,4-Dichlorobenzene	$\mu\text{g m}^{-3}$	7 days	indoor
VOCs 2-methylpentane, Methylene chloride, Methylcyclopentane, Chloroform, 2-methylhexane, Cyclohexane, Benzene, Heptane, Trichloroethylene, Methylcyclohexane, Toluene, Tetrachlorethylene, Ethylbenzene, m-Xylene, p-Xylene, o-Xylene, Styrene, 1,3,5-Trimethylbenzene, 1,4-Dichlorobenzene	$\mu\text{g m}^{-3}$		indoor, outdoor
Radon long-term	Bq m^{-3}	2-3 months	indoor
Radon short-term	Bq m^{-3}	3 days	indoor
Microplastics (MP)	Particles cm^{-2}	7 days	indoor

Chemical characterisation of household dust included determination of eleven polycyclic aromatic hydrocarbons (PAHs) from vacuum cleaner bags obtained from 117 households. PM_{10} fraction of particulate matter was sampled and measured gravimetrically in 94 households, while PAHs in PM_{10} were determined in 92 households. Nineteen volatile organic compounds (VOCs) were determined in 90 households applying active sampling over 50-minute sampling periods, while in 20 households weekly VOC samples were collected. The activity concentration of radon was determined in 81 and 67 households considering short-term and long-term exposure, respectively. Microplastics (MP) samples were collected in 30 households.



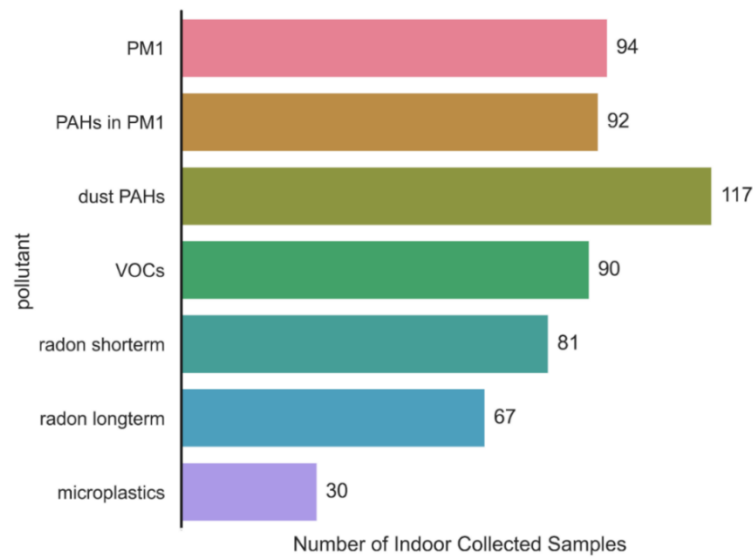


Figure 14 Total number of indoor air samples collected for each pollutant in Zagreb households

Whenever possible, outdoor measurements of PM₁, PAHs in PM₁, and VOCs were carried out in parallel with indoor measurements. In total, 82, 92 and 80 indoor-outdoor pairs were collected for PM₁, PAHs in PM₁ and VOCs, respectively. Certain outdoor PM₁ samples were excluded from analysis due to mechanical damage of filter edges or concentrations near the detection limits.

The figures below show the seasonal concentrations and variations of PM, VOC, and CO₂.

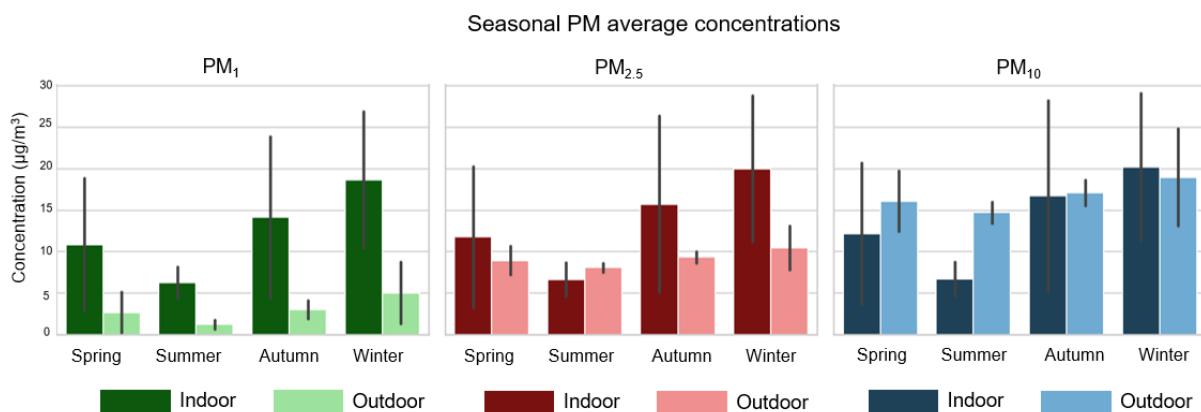


Figure 15 Comparison of seasonal particulate matter (PM₁, PM_{2.5}, PM₁₀) average concentrations between indoor and outdoor environments (in µg/m³).



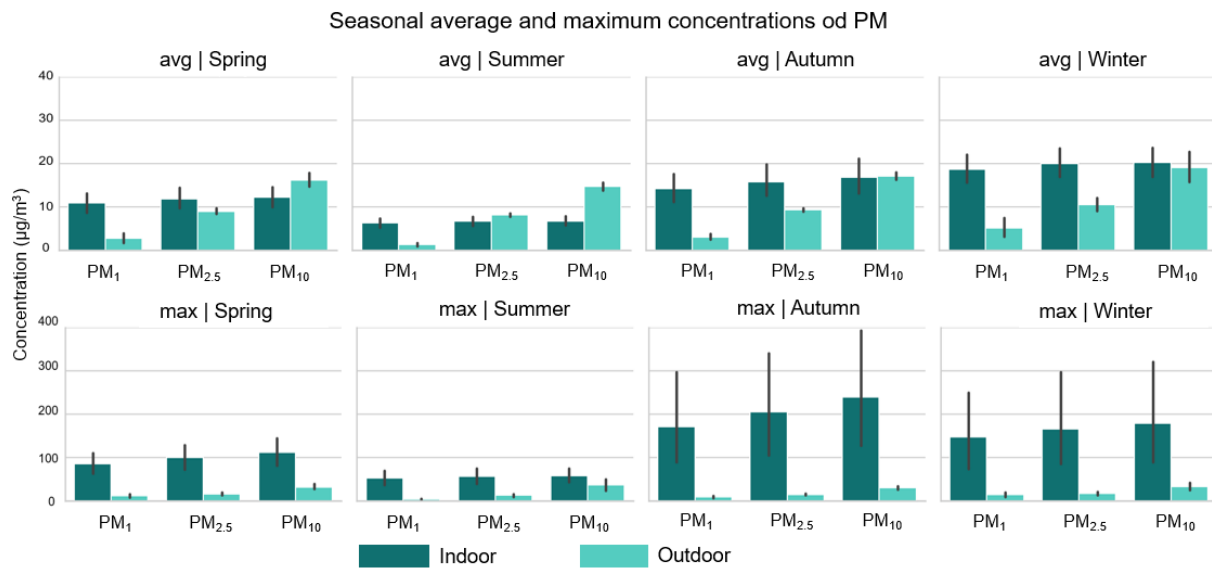


Figure 16 Seasonal variability of indoor and outdoor PM concentrations: minimum, average, and maximum values (in $\mu\text{g}/\text{m}^3$).

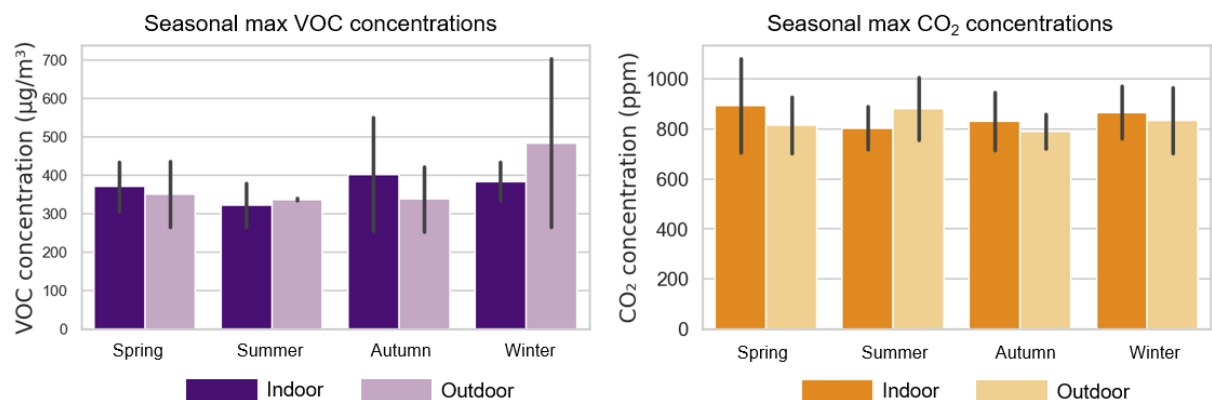


Figure 17 Seasonal variation in maximum VOC and CO₂ concentrations measured indoors and outdoors.

5.3 Report on microbiome data in dust samples

Introduction

Contaminants such as particulate matter (PM), volatile organic compounds (VOCs), and biological agents (pollen, house dust mites, bacteria, fungi, etc.) contribute significantly to poor IAQ, which is linked to a range of health problems such as asthma and acute respiratory infections in both adults and children. While chemical pollutants are relatively well studied, the role of biological pollutants, particularly the microbiome, is less understood. Therefore, the aim of this sub-deliverable was to analyse the diversity and



abundance of the dust microbiome (bacteria and fungi) in the household dust of asthmatic and healthy children, which will help gain a deeper understanding of the interaction between the microbiome and environmental factors, and their potential impact on asthma development.

Results

Microbiome was analysed from dust samples collected within the Zagreb pilot. Dust was sampled from child mattresses. Children with asthma and healthy controls have been sampled from 131 households and out of the total 178 collected bed dust samples, 175 samples were successfully sequenced for bacteria and 172 samples for fungi. Sequencing was performed on the Illumina MiSeq platform at the Laboratory for Molecular Anthropology, Centre for Applied Bioanthropology, Zagreb, Croatia. This sequencing effort yielded a total of 11,177,315 bacterial reads, with an average of 65,579 bacterial reads per sample. From these reads, 28,695 amplicon sequencing variants (ASVs) were generated using the DADA2 algorithm, which identifies unique sequences by correcting sequencing errors without clustering similar reads. This analysis was performed in Qiime2, an open-source bioinformatics platform widely used for microbiome data processing and analysis, at the Institute of Environmental Biotechnology, Graz University of Technology, Graz, Austria. These ASVs were subsequently classified into 42 bacterial phyla and 1,542 bacterial genera using the vsearch algorithm against the Silva database. The bacterial samples were dominated by *Firmicutes* (48.5%), followed by *Proteobacteria* (23.3%) and *Actinobacteria* (21.5%). On genus level, *Staphylococcus* (27.6%), *Corynebacterium* (10.6%) as well as the rare taxa (taxa with a relative abundance below 5%) (41.8%) were the most abundant constituents. For the fungal samples, a total of 38,772,509 reads were generated, averaging 63,870 fungal reads per sample. From these reads 13,518 ASVs were generated, which were assigned to 17 fungal phyla and 1,363 fungal genera using the Unite database. The fungal samples were dominated by *Ascomycota* (60.7%) and *Basidiomycota* (38.2%). On genus level, *Malassezia* (25.8%), *Cladosporium* (10.4%) as well as the rare fungal taxa (taxa with a relative abundance below 5%) (49%) were the most abundant constituents. Rarefaction analysis indicated that the sequencing effort was successful and sufficient, for both bacteria and fungi, for further downstream analysis, as a sequencing depth of 15,000



reads per sample effectively captured the microbial diversity. The report on the success of the performed microbiome sequencing from dust samples and obtained bacterial and fungal taxa is provided within this deliverable, while downstream analyses that include correlations with asthma and other metadata will be reported in WP3 (D3.1.c/d) and WP5 (D5.2).

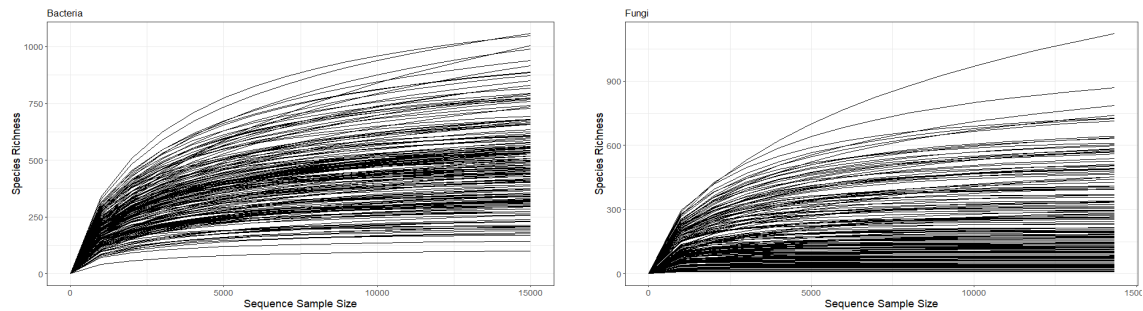
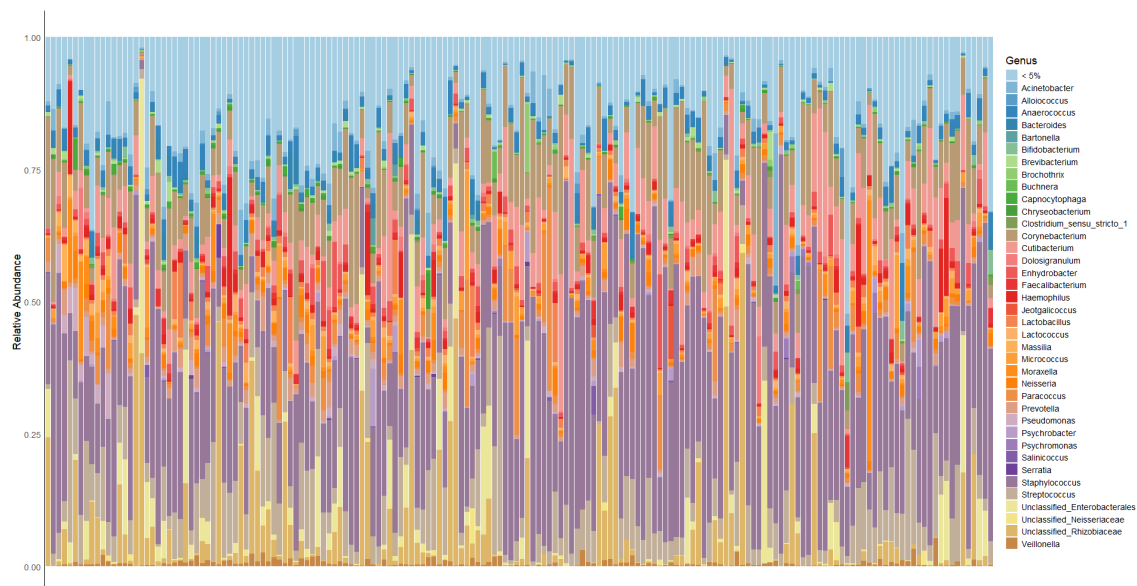


Figure 18 Rarefaction analysis for bacteria (left) and fungi (right).



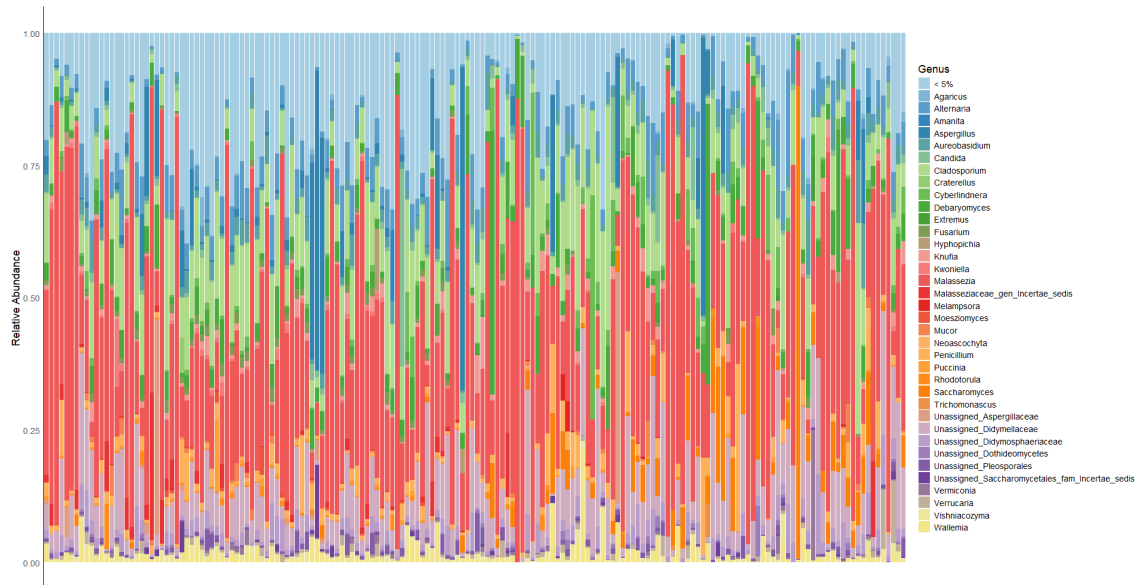


Figure 19 Relative abundance of bacteria (upper) and fungi (lower) in the bed dust at the genus level.

Summary

The sub-deliverable focused on analysing the microbiome in household dust samples collected from the Zagreb pilot, specifically from mattresses in homes of asthmatic and healthy children. Out of 178 collected samples, 175 were successfully sequenced for bacteria and 172 for fungi, confirming a high success rate and validating the methodology used. The sequencing depth of 15,000 reads per sample was sufficient to capture the microbial diversity, ensuring the robustness of the data for further analysis. The microbial profiling revealed that bacterial communities were dominated by *Firmicutes* (48.5%), *Proteobacteria* (23.3%), and *Actinobacteria* (21.5%), with *Staphylococcus* and *Corynebacterium* among the most abundant genera. Fungal communities were primarily composed of Ascomycota (60.7%) and Basidiomycota (38.2%), with *Malassezia* and *Cladosporium* being the most common genera. A notable portion of both bacterial and fungal populations consisted of rare taxa, underscoring the complexity of indoor microbiomes. These results expand the understanding of the microbial composition in indoor environments, especially in children's bedrooms.



5.4 Report on genomic instability data in children related to IAQ.

Methodology Overview

Human biomonitoring serves as a cornerstone for assessing exposure to environmental contaminants and their associated health risks, particularly in vulnerable populations such as children. This methodology involves the measurement of specific biomarkers in biological matrices to both quantify internal doses of pollutants and evaluate resultant biological effects (Zare Jeddi et al., 2022¹). To investigate genomic instability linked to IAQ, two well-established molecular biology and cytogenetic techniques were applied: the single-cell gel electrophoresis (comet) assay and the cytokinesis-block micronucleus (CBMN) assay. The comet assay is recognised for its high sensitivity in detecting a broad spectrum of DNA damage, including single- and double-strand breaks, alkali-labile sites, and DNA lesions arising from incomplete excision repair processes (Collins et al., 2023²). In parallel, the CBMN assay provides quantitative insights into chromosomal instability through the analysis of micronuclei (MNI), nuclear buds (NBUDs), and nucleoplasmic bridges (NPBs), markers indicative of genotoxic effects and chromosomal aberrations (Fenech, 2007³). The combined use of these complementary assays enables a robust evaluation of DNA and chromosomal damage associated with exposure to indoor air pollutants. These biomarkers were assessed alongside individual-level data on anthropometric characteristics, environmental exposures, and lifestyle factors obtained via structured questionnaires, allowing for integrated interpretation of genotoxic outcomes in context.

1 Zare Jeddi M, Hopf NB, Louro H, Viegas S, Galea KS, Pasanen-Kase R, Santonen T, Mustieles V, Fernandez MF, Verhagen H, Bopp SK, Antignac JP, David A, Mol H, Barouki R, Audouze K, Duca RC, Fantke P, Scheepers P, Ghosh M, Van Nieuwenhuijse A, Lobo Vicente J, Trier X, Rambaud L, Fillol C, Denys S, Conrad A, Kolossa-Gehring M, Paini A, Arnot J, Schulze F, Jones K, Sepai O, Ali I, Brennan L, Benfenati E, Cubadda F, Mantovani A, Bartonova A, Connolly A, Slobodnik J, Bruinen de Bruin Y, van Klaveren J, Palmen N, Dirven H, Husøy T, Thomsen C, Virgolino A, Rössli M, Gant T, von Goetz N, Bessems J. Developing human biomonitoring as a 21st century toolbox within the European exposure science strategy 2020-2030. *Environ Int.* 2022 Oct;168:107476.

2 Collins, A., Møller, P., Gajski, G., Vodenková, S., Abdulwahed, A., Anderson, D., Bankoglu, E. E., Bonassi, S., Boutet-Robinet, E., Brunborg, G., Chao, C., Cooke, M. S., Costa, C., Costa, S., Dhawan, A., de Lapuente, J., Bo', C. D., Dubus, J., Dusinska, M., Duthie, S. J., ... Azqueta, A. (2023). Measuring DNA modifications with the comet assay: a compendium of protocols. *Nature protocols*, 18(3), 929–989.

3 Fenech M. Cytokinesis-block micronucleus cytome assay. *Nat Protoc.* 2007;2(5):1084-104.



Results

Table 7 Descriptive Statistics for DNA Damage Measured by the Comet Assay (Tail Intensity)

Mean	Standard Deviation	Median	Range		N
			Minimum	Maximum	
1.81	1.18	1.44	0.41	5.84	205

This table presents descriptive statistics for the comet assay descriptor tail intensity, used to assess DNA strand breaks in peripheral blood cells of children (age: 5 –18). The values reflect the distribution of DNA damage across the study population (N = 205). The tail Intensity descriptor represents the percentage of DNA migrating into the comet tail, with higher values indicating increased DNA strand breakage. Reported descriptive statistics include the mean, standard deviation, median, minimum, and maximum values observed.

Table 8 Descriptive Statistics for Chromosomal Damage Measured by the CBMN Assay (Frequency of MNi)

Mean	Standard Deviation	Median	Range		N
			Minimum	Maximum	
4.29	2.50	4	0	12	118

This table summarises the descriptive statistics for the frequency of micronuclei (MNi), a key indicator of chromosomal damage, as measured by the CBMN assay in peripheral blood lymphocytes of children (age: 5 –18). The MNi frequency reflects the number of micronuclei observed per 1,000 binucleated cells, serving as a biomarker of chromosomal instability. The table reports the mean, standard deviation, median, minimum, and maximum values observed across the study population (N = 118).



6 P4 – Filtration Pilot

Indoor air filtration is vital for improving IAQ in public buildings. This pilot focused on buildings using ASC-installed ventilation and air conditioning systems to identify which pollutants are most effectively removed by these filters. The study aimed to establish pathways for IAQ improvement and will result in recommendations for efficient filters, optimal maintenance schedules, and filter replacement periods. Additionally, the pilot gathered data on user habits and comfort in office spaces using low-cost sensors from partners ASC, LAS, WINGS, and THIN to monitor ambient pollution.

Pilot deliverables:

P4.1 Report on best filtration system maintenance practices to improve IAQ.

P4.2 Report on filtration system efficiency and potential technological innovation.

6.1 Report on best filtration system maintenance practices to improve IAQ

Introduction

IAQ is a key determinant of occupant health, comfort, and productivity, especially in offices and commercial spaces. Particulate matter (PM_1 , $PM_{2.5}$, and PM_{10}) originates from both indoor activities (cooking, movement, office equipment) and outdoor infiltration. Filtration systems such as HVAC filters and portable air purifiers are widely used to manage these pollutants. However, their effectiveness depends not only on filter quality and maintenance but also on real-world conditions like airflow patterns and device placement.

This report reviews best practices in filtration system maintenance and critically evaluates findings from a two-week pilot experiment conducted in two office spaces. Contrary to expectations, the experiment showed no clear reduction in PM levels despite daily filter replacement, prompting a re-examination of filtration effectiveness in practical scenarios.

Filtration Pilot Overview

The pilot study was conducted between March 21 and April 4 in two indoor environments:

- Small Office (20 m²): 3 occupants, purifier near a window or the floor, sensors on floor and desk.



- Office Kitchen (50 m²): High foot traffic, purifier on a tall closet (approx. 1,6 m), sensors near window and printer on opposite sides of the room.

Sensors used in the experiment were sourced from all three of our providers: WINGS, LabService Analytica (LAS), and Thinnect. In addition, an Air Metrics MiniVol sampler was used to capture the mass concentration of the PM₁ particle fraction. Both environments employed daily filter replacement to ensure maximum theoretical filtration performance, and sensor readings were collected continuously. Both environments used daily filter replacement to ensure maximum theoretical filtration performance. Sensor readings were collected continuously.

Key Finding: PM₁, PM_{2.5}, and PM₁₀ levels did not show consistent or significant decreases compared to baseline levels, even with fresh filters used daily. This unexpected result suggests that filter maintenance alone may not guarantee improved IAQ, especially under certain room dynamics or if filtration systems are improperly sized, placed, or overwhelmed by pollution sources. Figure 20 and Figure 21 show results from the two indoor environments described above, indicating that the filter did not reduce particle concentrations but instead may have contributed to the resuspension of particles within the room. Although the figures display only PM₁₀, both smaller particle fractions follow the same trend.

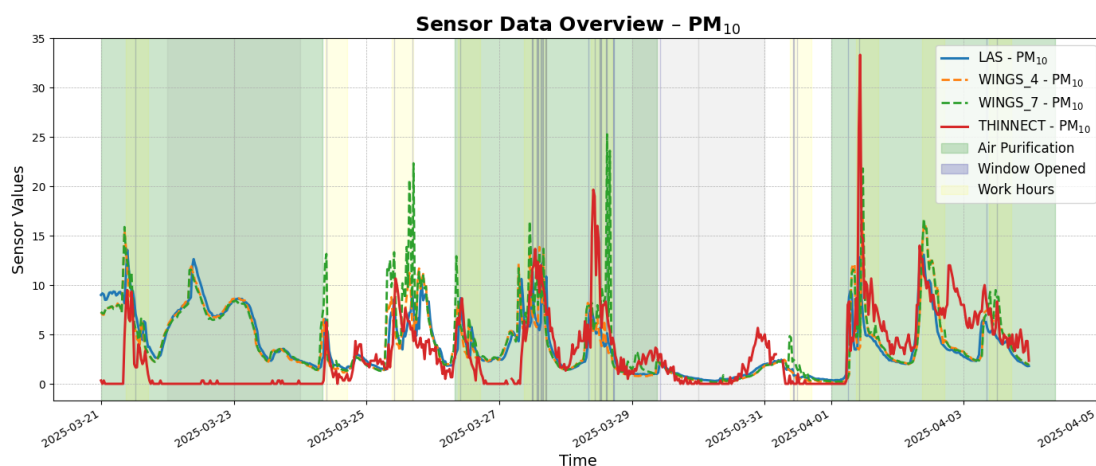


Figure 20 PM₁₀ concentrations over time in the small office with daily filter replacement.



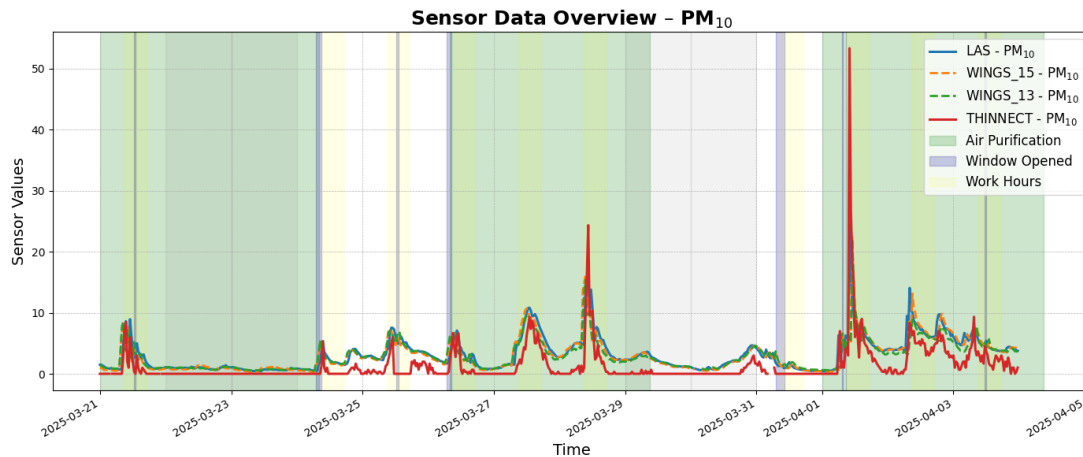


Figure 21 PM₁₀ concentration trends in the high-traffic office kitchen.

As stated earlier, to ensure the accuracy of sensor readings, we used the Air Metrics MiniVol sampler to collect PM₁ samples. PM₁ mass concentrations were determined gravimetrically and compared to the readings from the sensors. Figure 22 shows how the low-cost sensors (LCS), provided by our sensor partners, compared to IMI's gravimetric device (MiniVol). The results indicate that the sensors closely follow the measurements from the gravimetric method, suggesting that the sensors did not malfunction.

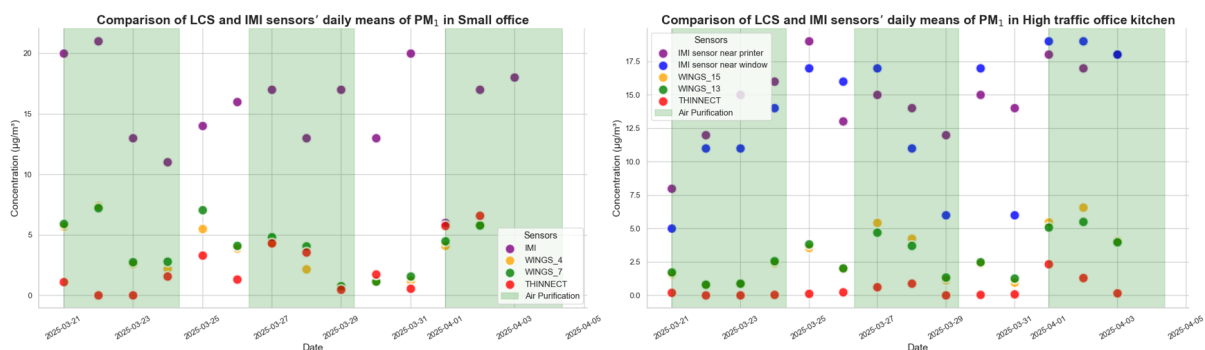


Figure 22 Comparison of daily mean PM₁ concentrations measured by low-cost sensors (LCS) and the Air Metrics MiniVol sampler.

Why Maintenance Still Matters

Despite the disappointing pilot outcome, maintenance remains a cornerstone of filtration efficacy when filters do have a measurable effect, it is only when they are clean, correctly installed, and replaced at proper intervals. Dirty or overloaded filters can:

- Become sources of pollutants themselves (e.g. Mold, dust release)
- Reduce airflow and CADR, limiting the purifier's ability to circulate and clean air



- Lead to system inefficiencies or failure (especially in HVAC setups)

Regular maintenance is still necessary to ensure the device functions as intended, even if, in some cases, external factors blunt its effectiveness.

Understanding the Lack of Effectiveness in the Experiment

Several reasons may explain why daily filter changes did not lead to measurable PM reduction:

- Inadequate purifier placement (e.g., near a window or high up on a closet) may have resulted in poor circulation of polluted air into the device.
- Insufficient purifier capacity for the room volume or pollution load.
- Internal pollution sources (e.g., foot traffic, cooking) may have outpaced the purifier's cleaning rate.
- Short dwell time or lack of air mixing, meaning clean air did not distribute uniformly in the space.
- Sensor positioning may have missed local improvements near the purifier (though previous studies indicated minimal effect of sensor height).

These insights underscore a broader industry lesson: filtration must be part of a holistic IAQ strategy, not a standalone solution.

Best Maintenance Practices

Regardless of the pilot results, following best practices ensures filters can work when other conditions are optimised:

Filter Type	Recommended Maintenance	Notes
HEPA (Portable)	Replace every 6–12 months; inspect monthly	Ensure tight fit and no bypass
Pre-Filter	Clean/vacuum monthly; replace every 3 months	Extends HEPA lifespan
Carbon Filter	Replace every 3–6 months	Targets odors/VOCs, not PM directly
HVAC (MERV 13+)	Inspect monthly; replace every 2–3 months	Use pressure gauges for timing
Electronic Cleaners	Wipe collector plates monthly	Avoid ozone generation



Use differential pressure readings, visual inspections, and built-in indicators (if available) to fine-tune replacement schedules.

Implications and Recommendations

The experiment's unexpected result offers an important reminder: maintenance is necessary but not sufficient. Facilities should:

- Assess purifier specs vs. room volume and pollution sources
- Optimise device placement to ensure air circulation
- Use supplementary IAQ strategies: increase ventilation, reduce indoor sources, and monitor air quality continuously
- Review and test purifier performance regularly—not just assume it works

In high-pollution areas, use multiple purification layers (e.g., HVAC + portable units) and consider CO₂ and VOC monitoring alongside PM.

Conclusion

This study involved a small number of filtration systems and did not test other types of purifiers. Therefore, the conclusions apply only to the systems tested and cannot be generalised to all purifiers. While filter maintenance remains essential for any air purification system, the pilot experiment highlights a sobering reality: even well-maintained filters may not improve IAQ unless system design, usage context, and environmental factors are also addressed. This nuanced understanding should inform future IAQ management plans and guide smarter investments in indoor environmental quality.

6.2 Report on filtration system efficiency and potential technological innovation.

Introduction

Maintaining high IAQ is vital for human health and productivity, particularly in workspaces where people spend long periods in close quarters. Air filtration systems, such as the iTherapy Model 100 and iTherapy Elfy, claim to reduce airborne PM, VOCs, and biological contaminants using multi-stage filtration technologies. This report evaluates the real-world performance of such a system through a two-week pilot study in two office environments



and critically compares the results with expectations based on current air purification technologies.

Pilot Study Overview

A pilot experiment was conducted over 14 days in two environments:

- A small office (20 m²) with three regular occupants and limited ventilation.
- An office kitchen (50 m²) with higher foot traffic and episodic particle emissions (e.g., during cooking or printing).

Sensors used in the experiment were sourced from all three of our providers: WINGS, LabService Analytica (LAS), and Thinnect. In addition, an Air Metrics MiniVol sampler was used to capture the mass concentration of the PM₁ particle fraction. Both environments employed daily filter replacement to ensure maximum theoretical filtration performance, and sensor readings were collected continuously. The iTherapy Model 100 unit was installed in the office kitchen, and the iTherapy Elfy was installed in the small office and operated continuously. PM₁, PM_{2.5}, and PM₁₀ were measured using strategically placed sensors (e.g., near windows, printers, tables, and floors). Notably, filters were replaced daily to ensure optimal filter condition.

Key Findings: No Significant Improvement in PM Levels

Despite the unit's operation and fresh filters, the experimental data did not show a meaningful reduction in PM concentrations (PM₁, PM_{2.5}, and PM₁₀) in either environment:

- In the small office, expected improvements in background PM_{2.5} levels were not observed. Sensor data showed consistent particulate levels whether the purifier was active or not, suggesting limited or no effective removal of airborne particles.
- In the office kitchen, similar trends were noted. Even during activity spikes (e.g., during lunch or printing), the air purifier did not significantly reduce PM₁₀ or PM_{2.5} concentrations after events that typically raise particulate levels.

These results contrast sharply with the iTherapy Model 100's advertised >80–90% reduction in PM_{2.5}, raising concerns about its real-world filtration efficacy or room-size suitability.



Discussion: Why the System May Have Underperformed

Several possible factors may explain the discrepancy between theoretical efficiency and observed outcomes:

- **Airflow Dynamics and Purifier Placement:** The unit may not have provided sufficient airflow exchange to reach the entire room volume effectively, especially in the larger kitchen. Real-world placement (e.g., near a window or on top of a cabinet) might not have allowed effective circulation or pollutant capture.
- **Filter Bypass or Leaks:** If air bypassed the filter media (e.g., due to poor sealing or internal leaks), particulate-laden air could have recirculated without effective treatment.
- **Sensor Positioning and Mixing:** Though previous research suggested sensor placement had minimal impact, if pollutants were unevenly distributed or localised (e.g., cooking smoke near the source), sensor readings may not have captured small, localised reductions.
- **Insufficient CADR (Clean Air Delivery Rate):** The iTherapy's rated capacity ($\sim 30 \text{ m}^2$ optimal coverage) may not have been enough to handle the pollution load in dynamic spaces, even with perfect filtration efficiency per pass.

Implications for Technological Innovation

Given the ineffectiveness observed in real use, this study highlights the need for innovation and improved system design:

- **Improved Airflow Engineering:** Devices should include adaptive fans and better mixing mechanisms to ensure uniform air treatment across the room, especially in larger or high-traffic areas.
- **Sensor-Driven Smart Control:** Integrating real-time PM and VOC sensors could allow the system to modulate its power dynamically, targeting spikes in pollutants with higher intensity airflow or UV power.
- **Transparent Efficiency Metrics:** Manufacturers should report real-world CADR and decay rates in dynamic, occupied environments rather than relying solely on lab-based HEPA metrics.



- **Advanced Filter Media:** Incorporating electrospun nanofiber membranes or metal-organic frameworks (MOFs) could potentially enhance the capture of ultrafine and gaseous pollutants, but only if airflow is sufficient.

Conclusion and Recommendations

This pilot study offers a critical real-world test of the iTherapy Model 100 and iTherapy Elfy. Despite promising specifications (multi-layer HEPA filtration, UV-C, ionization), the system did not significantly reduce PM concentrations in either of the tested environments. These findings underscore the gap between theoretical filtration claims and practical performance under everyday use.

Future air purification systems must prioritise:

- Validated real-world efficacy testing in dynamic, occupied spaces.
- Enhanced CADR and air mixing design, especially for mid-sized rooms.
- Technological upgrades such as adaptive controls, better flow optimisation, and smarter filter media.

Only through these improvements can indoor air filtration systems meet their intended role of improving health and air quality reliably across varied use scenarios.



7 C1 – Evaluation of low-cost sensorics

Recent advancements in low-cost compact environmental sensorics allowed researchers, community groups, students, and citizen scientists to deploy them for ubiquitous and time-resolved IAQ monitoring. However, despite their great potential, low-cost environmental sensorics are still under development, and further information about their data quality, accuracy, and best practices for using them is required. C1 is focused on a comprehensive performance evaluation of multiple consumer-grade multi- and single-parameter sensors in detecting particulate matter (PM_{2.5}, PM₁₀), CO₂, NO_x, TVOCs, temperature, RH, etc.

Pilot deliverables:

C1.1 Intercomparison report on low-cost sensorics against reference instruments.

C1.2 Calibration procedures for low-cost sensorics.

C1.3 Report on usability, reliability, sustainability, and availability (URSA) of low-cost sensorics.

7.1 Intercomparison report on low-cost sensorics against reference instruments.

The information presented here summarises the findings reported in Deliverable C1.1, which were obtained during the intercomparison of low-cost sensors with reference air quality monitoring instruments, following the methodologies detailed in Deliverables D3.1 and D3.2.

The low-cost sensors were characterised and intercompared under controlled (laboratory), semi-real, and real-world scenarios to estimate the unit-to-unit variabilities (precision), their deviation from reference-grade instruments (accuracy), and their response to changes to environmental parameters (relative humidity, temperature, and pollution sources). The reference instruments were categorised into four groups: A: Primary standard = Instruments using methods considered as reference by governing bodies; B: Secondary = Instruments which have been calibrated against the primary standard; C: Tertiary = Mid-cost instruments with certification from governing bodies; D: Quaternary = Identical sensors considered as “master devices” calibrated in their own labs. The table below presents the experiments performed, the pollutants measured, and the type of reference instruments used.



Table 9 Summarised description of intercomparison experiments

Experiment	Accuracy (list of parameters)	Reference instrument category	Precision (# of units)			
			LAS	WINGS (Indoor)	WINGS (Outdoor)	THIN
Laboratory						
Chamber experiments*	PM, CO ₂	B, C	3	3	3	3
Regular laboratory	PM, CO ₂	B, C	3	3	3	0
Semi-real-world						
Office	PM, CO ₂ , gases	C	3	3	3	3
Real-world						
Outdoor Zagreb	PM, O ₃ , SO ₂ , NO, NO _x , CO ₂	A	0	0	1	0
Vilnius campaign	PM, VOC, CO ₂	B, C	4	5	0	0
Outdoor rooftop Leipzig	PM, O ₃ , SO ₂ , NO, NO _x , CO ₂	A	3	0	2	3
Zagreb collocation	All WINGS parameters	D	3	3	3	3

The methods for analysis of sensor performance are described in Deliverable 3.1. The thresholds set for each performance metric were: $R^2 \geq 0.7$, Slope = 1.0 ± 0.35 , Intercept = $\pm 5 \mu\text{g}/\text{m}^3$, Normalised root mean square error (NRMSE) $\leq 30\%$, and Coefficient of variance (CV) $\leq 30\%$. The tables below contain exemplary results of the performance metrics calculated for two types of experiments, for the three sensor providers characterised in the experiments.

Table 10 Summarised performance metrics for laboratory chamber intercomparison

Parameter	R ²	Slope	Intercept	nRMSE [%]*	CV [%]**	remarks
Laboratory: Dedicated chamber experiments for each parameter (5 min resolution)						
LAS						
PM _{2.5} vs C	0.95 - 0.96	0.59 - 0.66	0.63 - 0.84	85.6 - 103	18.3	Aroma stick smoke
PM _{2.5} vs B	0.73 - 0.78	0.34 - 0.39	-1.18 - 0.05	84.5 - 89.7		
PM ₁₀ vs C	0.94 - 0.96	0.55 - 0.74	0.7 - 0.74	93.1 - 110	18.4	
PM ₁₀ vs B	0.66 - 0.7	0.3 - 0.34	-0.59 - 0.61	89.4 - 93.4		
CO ₂ vs C	0.99 - 1.00	0.98 - 1.05	66.6 - 118	2.09 - 9.78	3.5	Pure CO ₂
CO ₂ vs B	0.99 - 1.00	0.89 - 0.95	191 - 223	3.76 - 4.8		



VOC vs C	0.47 - 0.64	0.08 - 0.09	559 - 583	97.7 - 98.8	4.74	Acetone
WINGS (Indoor)						
PM _{2.5} vs C	0.92 - 0.95	0.61 - 0.68	0.79 - 1.22	83.1 - 99.5	19.7	Aroma stick smoke
PM _{2.5} vs B	0.71 - 0.77	0.36 - 0.39	-0.22 - 1.52	82.8 - 87.1		
PM _{1,10} vs C	0.91 - 0.96	0.57 - 0.66	0.61 - 1.27	87.5 - 106	20 - 20.2	
PM _{1,10} vs B	0.67 - 0.77	0.32 - 0.39	-0.65 - 1.53	83.6 - 91		
CO ₂ vs C	0.45 - 0.46	-0.26 - -0.23	1398 - 1416	62.5 - 63.7		Pure CO ₂
CO ₂ vs B	0.44 - 0.45	-0.23 - -0.21	1359 - 1372	67.6 - 68.8		
VOC vs C	0.74 - 0.67	0.01 - 0.07	-1.26 - 23.2	105	2.59 - 13	Acetone CV with: CO, VOC
THIN						
CO ₂ vs C	0.99 - 1.00	0.87 - 0.97	-30.3 - 288	1.65 - 6.05		Pure CO ₂
CO ₂ vs B	0.97 - 0.99	0.84 - 0.890	141 - 310	3.24 - 8.55		

*If only one number is given, only one parameter is measured by the considered reference

**If only one number is given, only one parameter of the given air-quality parameter group is measured by the device.

Table 11 Summarised performance metrics for an office setting intercomparison

Parameter	R ²	Slope	Intercept	nRMSE [%]*	CV [%]**	remarks
Semi-real world: Office (5 min resolution) vs C						
LAS						
PM _{2.5}	0.97 - 0.98	0.99 - 1.02	-0.21 - -0.13	20 - 21.4	5.34	
CO ₂	0.97 - 0.98	0.97 - 1.04	-6.67 - 141	6.85 - 19	8.97	
PMs (PM ₁₀)	0.86 - 0.87	0.76 - 0.78	-0.2 - -0.14	52.2 - 54.5	5.54	
Gases (VOC)	0.29 - 0.41	0.01 - 0.01	146 - 179	103 - 105	2.48 - 8.59	CV with: CO, O ₃ , NO ₂ , VO
WINGS (Indoor)						
PM _{2.5}	0.96 - 0.97	0.83 - 1.01	-0.18 - 0	22.4 - 33.2	14.9	
CO ₂	0.54 - 0.55	0.34 - 0.35	389 - 400	35.4 - 36.4	2.38	
PM ₁ & PM ₁₀	0.87 - 0.99	0.66 - 1.10	-0.2 - 0.01	17.5 - 60.9	13.6 - 15.8	
Gases (VOC)	0.13 - 0.14	0.11 - 0.12	177 - 192	89.2 - 91.1	7.45 (VOC) - 142 (CO)	CV with: CO, VOC
THIN						
CO ₂	0.94 - 0.95	0.88 - 0.95	7.5 - 78.9	7.38 - 9.38	3.03	

*If only one number is given, only one parameter is measured by the considered reference

**If only one number is given, only one parameter of the given air-quality parameter group is measured by the device.



This project has received funding from the European Union's Horizon Europe Framework Programme under grant agreement N° 101057497.

The intercomparison experiments conducted served to build on the long-term objectives. By evaluating multiple commercially available, low-cost sensors against reference-grade instruments, the performance of the devices was systematically assessed across key criteria, including accuracy and precision. The controlled experiments in the laboratory, which introduced variations in temperature and relative humidity, further allowed the investigation of sensor sensitivity to environmental factors and identified potential limitations or calibration needs. These comparative analyses not only allowed the characterisation of sensors' intervariability but also provided a robust foundation for suggesting the most suitable low-cost air quality monitors for long-term indoor air quality applications based on performance, cost-effectiveness, and operational practicality.

7.2 Calibration procedures for low-cost sensorics.

Calibration of low-cost sensors is fundamental to ensure reliable and informative indoor air quality measurements. Despite their affordability, usability, and accessibility, commercially available sensors often exhibit variable performance, which is influenced by environmental factors such as temperature and humidity, as well as production quality.

Proper calibration enables optimised use and informed comparisons by providing knowledge of accuracy, maintenance needs, and long-term reliability. It also facilitates the characterisation of unit-to-unit variabilities and environmental sensitivities, both of which are critical for assessing their suitability in diverse indoor scenarios. Ultimately, robust calibration practices support evidence-based recommendations for end-users, enabling them to select the most suitable and cost-effective monitoring solutions for sustained IAQ monitoring.

This section includes a summary of the procedures followed during the calibration of low-cost sensors by two sensor providers involved in the project: WINGS and Lab Service Analytica (LAS).

WINGS

Sensor calibration procedure and best practices



- Collocation of air sensors with reference-grade instruments before deployment:
Sensors should be placed next to high-quality reference monitors to ensure accurate baseline reading before deployment.
- Calibration should be performed in similar environmental conditions as deployment:
The environmental conditions at the collocation site should closely resemble those of the deployment location to improve the accuracy of the correction model.
- Collect calibration data for an adequate period to capture environmental variability (temperature, humidity, pollutant fluctuations): A sufficient calibration period is needed to account for different weather conditions and pollutant levels.
- Use regression models to correct sensor bias and improve data accuracy: Regression models (linear or machine learning-based) can be used to adjust sensor data to match reference values.
- Apply calibration equations to sensor outputs post-collocation: The derived correction model should be applied consistently to all sensor data before analysis.
- Regularly verify sensor accuracy by periodic collocation throughout deployment:
Recalibration should be done periodically to maintain accuracy and detect drift.

The calibration steps are summarised in the diagram below.

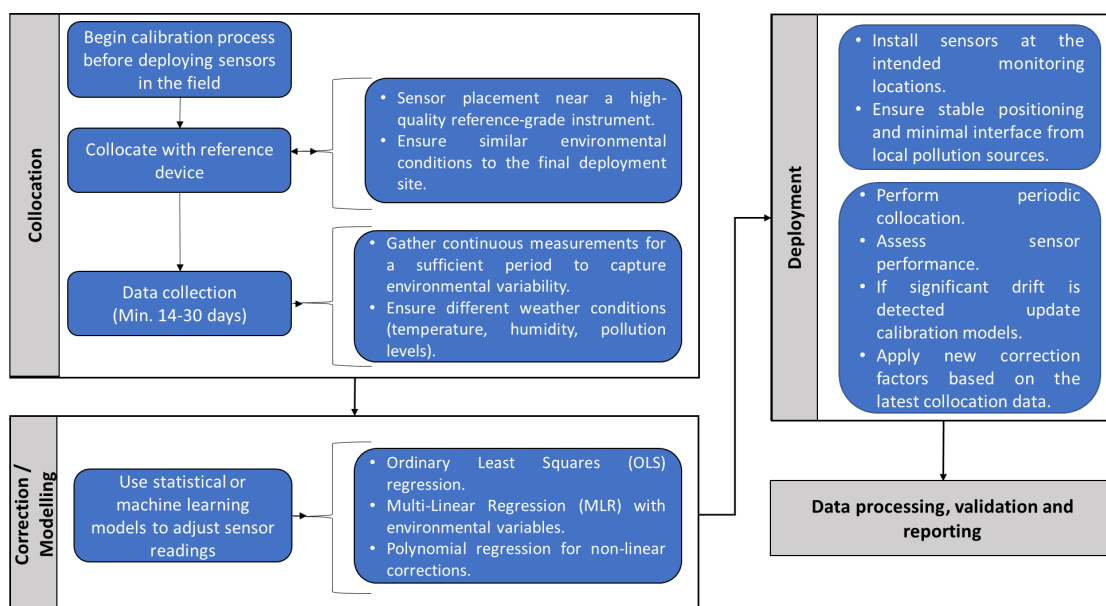


Figure 23 Diagram of calibration procedures - WINGS.

Duration of calibration:

- Collocation should last at least 30 days for 24-hour averaged data: This duration provides a robust dataset for capturing diurnal and daily pollutant variations.
- 14 days for hourly data to capture a range of conditions: A two-week period is often sufficient for understanding short-term variations in sensor accuracy.
- 7 days for minute-level data if high time resolution is required: Short-term deployments can be useful for applications where rapid pollutant fluctuations are being monitored.
- Calibration should be repeated seasonally or as needed based on sensor drift: Seasonal recalibration helps account for environmental changes that may impact sensor performance.

Sensor drift, seasonality, and calibration considerations

- Sensors may exhibit drift over time, requiring periodic recalibration: Sensors degrade due to environmental exposure, leading to gradual changes in sensitivity.
- Temperature, humidity, and interference from other pollutants can impact sensor readings: These factors can introduce variability and affect the accuracy of sensor measurements.
- Seasonal changes (e.g., increased humidity in summer, temperature inversions in winter) can influence sensor performance: Seasonal effects should be monitored to ensure data consistency.

LAS

Sensor calibration procedure and best practices

LAS's choice has been to focus on the unit's performance in terms of fluidics design and sensor housing, as well as the selection of hardware components. So, instead of working, as usual practice, on pre-processing the data, more work was done on post-processing the raw data. This approach enables LAS and its partners to evaluate sensor performance over time



and to have access to raw data for implementing further actions based on statistical and/or Machine Learning techniques.

- Manufacturing phase: An intercomparison of data and trends of each parameter has been done to assess the consistency and reproducibility of trends over time. In parallel, a visual inspection of locations where to place units occurs to collect static information about buildings, selected rooms, the kind of activities performed, and residents.
- Monitoring campaigns: During these activities, site visits are conducted periodically (at least every 2 months) to check the status of the units, resolve any connectivity issues, maintain the units from both hardware (HW) and software (SW) perspectives, as well as sensors where necessary. At the end of the 2-year survey period, routine maintenance activity will have to be conducted to replace the sensors. Especially the electrochemical sensors, which in our experience have a lifetime of less than 2 years.
- Post-processing stage: Data for scientific reports or publications, and the time series of each parameter are analysed to correct the minor drifts of some sensors (e.g., NO₂, CO₂, CO) by application of an offset, and some sensors that experienced technical problems during the observed periods are excluded from data analysis.

The steps followed by LAS in the sensor calibration procedures are shown in the diagram below.



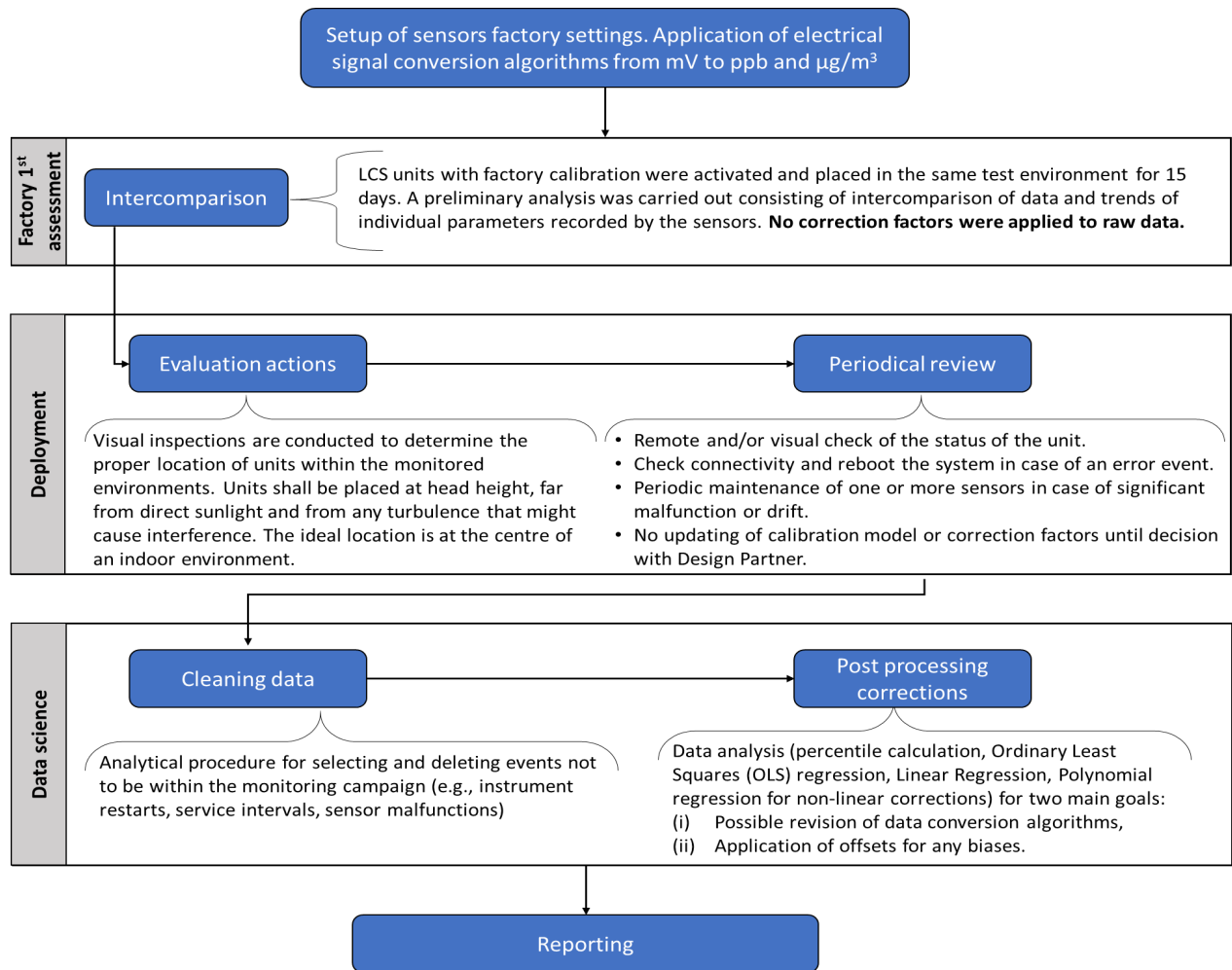


Figure 24 Diagram of calibration procedures - LAS.

WINGS and LAS reported similar calibration procedures and evaluated comparable key performance metrics (root mean square error, coefficient of determination, biases, percent or relative error, Pearson coefficient). Furthermore, the providers share the statistical models used for data analysis, such as Ordinary Least Squares (OLS) regression and Multiple Linear Regression (MLR). The calibration procedures described are intended to guarantee the highest quality measurements possible from low-cost sensors. Their characterisation and calibration enable the reduction of biases generated by sensitivities and artifacts that can compromise the quality of the information provided.



7.3 Report on usability, reliability, sustainability, and availability (URSA) of low-cost sensors.

The adoption of low-cost sensors for environmental monitoring and scientific research has rapidly increased over recent years. Features such as affordability, ease of deployment, and data availability have enabled the evaluation of higher spatial and temporal coverage of air pollution, bringing monitoring solutions to indoor areas. Evaluating and reporting on the usability, reliability, sustainability, and availability (URSA) of low-cost sensors for indoor air quality is essential to ensure their effective deployment in real-world settings, as these define their overall value, credibility, and long-term functionality in scientific and operational contexts. Usability refers to the ease with which sensors can be installed, operated, and maintained by various user groups, including non-specialist technicians. Reliability guarantees consistent and accurate performance over time and is usually evaluated by comparing the sensors to reference instruments. Sustainability helps identify long-term environmental impacts and feasibility, covering the long-term operability of sensors, including maintenance needs, component durability, and the availability of technical support. Availability refers to the ease with which sensors can be acquired, including production capacity, lead times, and access to spare parts. The optimal level of a product's availability occurs when a company successfully satisfies customer needs while preserving customer satisfaction.

To measure URSA of the low-cost sensors in the project, two surveys were created and disseminated among different participants: (i) a survey for technical users, and (ii) a survey for sensor providers. Below, a summary is provided for each survey.

This survey aimed to explore the user experience of project partners involved in the low-cost sensor installation, operation, maintenance, and intercomparison. This group includes sensor operators in pilots and campaigns, sensor operators in laboratory experiments, and pilot or campaign leaders. The survey was available online via EU Survey and consisted of 26 questions to evaluate the perception of sensors from three sensor providers. Answers were collected from five partners from the project. Exemplary questions for each component are shown in the figures below.



Usability

Product usability encompasses five key attributes: learnability, efficiency, memorability, error management, and subjective satisfaction. It helps to evaluate the user experience while using the product (Nielsen, 2010).

1. How would you rate the set up and configuration experience of the sensors?

	Very easy	Easy	Neutral	Difficult	Very difficult	Not applicable
* WINGS	☐	☐	☐	☐	☐	☐
* LAB SERVICE ANALYTICA	☐	☐	☐	☐	☐	☐
* THINNECT	☐	☐	☐	☐	☐	☐

Reliability

The effectiveness and reliability of sensors are typically evaluated by comparing them to reference instruments in laboratory settings under controlled conditions or in real-life scenarios. It also comprises the comparability with similar devices and their capacity to provide trustable, continuous, and understandable measurement data (Schalm et al., 2022).

6. How comparable were the particulate matter sensors to reference instruments (i.e., accuracy)?

	Comparable	Somehow comparable	Not comparable	Not applicable	No information available
* WINGS	☐	☐	☐	☐	☐
* LAB SERVICE ANALYTICA	☐	☐	☐	☐	☐
* THINNECT	☐	☐	☐	☐	☐

Sustainability

Sustainable products are those with positive social and/or environmental attributes, such as recycled or sustainable raw materials used in their production, socially fair production processes, positive community impacts, carbon footprint compensation, and mitigation, etc. These products usually inform consumers about their sustainable features (Bangsa & Schlegelmilch, 2020).

15. How energy-efficient are the sensors in terms of power consumption?

	Very efficient	Efficient	Neutral	Inefficient	Very inefficient	Not applicable
* WINGS	☐	☐	☐	☐	☐	☐
* LAB SERVICE ANALYTICA	☐	☐	☐	☐	☐	☐
* THINNECT	☐	☐	☐	☐	☐	☐

Availability

Product availability is a key element of the supply chain that ensures the timely provision of the right products to meet customer demand. The ideal level of product availability is when a company successfully satisfies customer needs while maintaining high levels of customer satisfaction (Imarticus.org, 2023).

19. Were the sensors available at the desired location when expected and needed?

	Available on time	Available shortly after	Available long time after	Not available	Not applicable
* WINGS	☐	☐	☐	☐	☐
* LAB SERVICE ANALYTICA	☐	☐	☐	☐	☐
* THINNECT	☐	☐	☐	☐	☐

Figure 25 Exemplary questions for the URSA survey for technical users.



This project has received funding from the European Union's Horizon Europe Framework Programme under grant agreement N° 101057497.

The comparison between the WINGS, LAS, and THINNECT sensors highlights notable differences in usability, reliability, and overall user experience. THINNECT stood out for its consistently smooth setup process and fast initialisation, though its interface was rated as neutral and lacked comparative accuracy data. LAS offered the most precise documentation and a user-friendly interface, with users reporting ease of access to data and a relatively reliable experience overall. In contrast, WINGS showed the most variability, with mixed feedback on setup, user interface, and readiness for use. While both WINGS and LAS had some validation against reference instruments, THINNECT lacked such comparative insights. All three sensors supported real-time and post-experiment data access, but only WINGS received a “very easy” rating for data accessibility. None of the sensors demonstrated notable sustainability features, and support availability varied across the board. Sensor providers were also asked about parameters to measure the URSA of their devices. Exemplary questions are shown in Figure 26.

Answers were collected from three participants from WINGS and LAS. In summary, both companies confirmed that they offer documentation and that their sensors are ready to use, requiring no additional setup. They also provide accuracy and precision data, though typically only upon request. Delivery times varied between the two providers: LAS typically requires over a month, while WINGS delivers within two to four weeks. Stock availability is more consistent for LAS (1–10 units), while WINGS notes variability depending on sensor type. Both companies offer replacements in the event of failure and provide access to software or measurement data. While LAS offers continuous customer support, WINGS reports intermittent availability. Finally, both offer bulk purchasing options.

Assessing URSA is essential for guiding procurement decisions, designing field campaigns, and informing development priorities for sensor manufacturers. The results obtained during this evaluation must be taken with caution, as the sample size is small and insufficient to calculate statistics and draw firm conclusions. Overall, the answers obtained provide an overview of the user experience and contrast it with the declarations of providers.

One additional survey was created for partners within the IDEAL Cluster, aiming to assess their user experience with low-cost sensors. At the time of presenting this report, the survey



is still open and has 13 answers. Results from the survey will be presented in IDEAL Cluster deliverables.

Usability	1. Do you provide your manuals or documentation with instructions to your clients?						
		Yes	No	Instructions are provided upon request			
	Answer	☐	☐	☐			
Reliability	2. Are your sensors ready to use? Do they require assembly by the users?						
		Ready to use	Simple assembling required		Complex assembling required		
	Answer	☐	☐		☐		
Sustainability	3. Do you report data on the accuracy of your sensors to your clients?						
		Yes	No	Provided upon request			
	Answer	☐	☐	☐			
Availability	4. Do you report data on the precision of your sensors to your clients?						
		Yes	No	Provided upon request			
	Answer	☐	☐	☐			
Usability	7. Do you incorporate carbon footprint estimations in your production process?						
		Yes	No	In progress	Foreseen		
	Answer	☐	☐	☐	☐		
Reliability	8. How much of your final product corresponds to recycled materials?						
		< 10%	10% – 30%	30% - 60%	60% - 90%	> 90%	None
	Answer	☐	☐	☐	☐	☐	☐
Sustainability	11. What is the typical lead time for receiving your sensors after placing an order?						
		< 1 week	1 week	2-4 weeks	> 1 month		
	Answer	☐	☐	☐	☐		
Availability	12. How many sensors do you have in stock?						
		None	1-10	10-100	>100	Nor applicable	Variable, depends on the sensor
	Answer	☐	☐	☐	☐	☐	☐

Figure 26 Exemplary questions for the URSA survey for sensor providers.

The surveys played a key role in supporting all long-term objectives within C1 by capturing insights that complement technical performance data. They enable the systematic evaluation of user experiences with various low-cost sensors, facilitating the segregation of devices based on criteria such as ease of use, perceived reliability, maintenance needs, and cost-effectiveness. Survey feedback can also highlight practical issues that may affect sensor variability or sensitivity in different environments, providing valuable context for laboratory findings. Most importantly, user input, combined with performance testing, enables the development of balanced and evidence-based recommendations for end-users, tailored to real-world needs and constraints.



8 C2 – Measurement campaign Sevilla

The IAQ measurement campaign in Sevilla focused on characterising indoor air pollutants and studying ventilation habits in schools, hospitals, residential areas, and public transport, particularly for vulnerable populations.

Pilot deliverables:

C2.1 Characterisation of indoor pollution physical-chemical properties in Sevilla metropolitan.

C2.2 Report on action strategies to improve IAQ.

C2.3 Workshops to promote awareness of IAQ and induce behavioural changes to reduce indoor air pollution.

C2.4 Implementation of data monitoring system open data in Seville with interoperable web services for data visualisation, data access and analysis.

8.1 Characterisation of indoor pollution physical-chemical properties in Sevilla metropolitan.

To characterise indoor air pollution in the metropolitan area of the city of Seville, continuous monitoring of various environmental parameters in indoor spaces was carried out. Specifically, data on temperature (T), relative humidity (RH), carbon dioxide concentration (CO₂), fine particulate matter (PM_{2.5}) and total volatile organic compounds (TVOCs) were recorded at a sampling frequency of 5 minutes.

The monitoring campaign has been carried out in four pilot buildings with different uses, which provides a more comprehensive and representative view of indoor air quality conditions in different urban contexts. The buildings and spaces evaluated are:

- ‘El Nido del Paraguas’: Kindergarten located in the city centre, where two classrooms have been monitored.
- St. Mary School: School located on the outskirts of the city, where three classrooms have been evaluated.
- Residential housing in multi-family building (6th floor), located on the outskirts, with one monitored room.



- **ASPACE:** Residence for people with cerebral palsy, also located in the periphery, where three rooms have been evaluated: dining room, double room and day activity room.

The inclusion of spaces with different uses (educational, residential and care), as well as their location both in the city centre and in peripheral areas, makes it possible to obtain a broader and more contrasted characterisation of indoor pollution. This diversity in the monitored environments provides valuable data on how activities, occupancy, ventilation and urban location can influence indoor air quality. It also allows comparisons to be made between environments with different levels of susceptibility, such as spaces dedicated to children or vulnerable people.

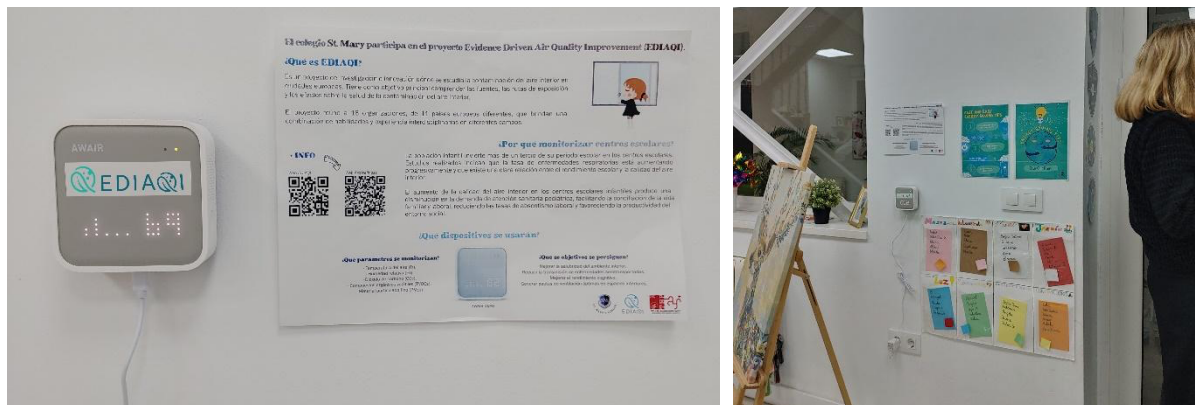


Figure 27 Measuring devices installed in schools.

In addition to the aforementioned buildings, environmental monitoring has been carried out inside the trains on Line 1 of the Seville metro. This line is approximately 18 kilometres long, connecting outer areas of the metropolitan area with the city centre. The route includes outdoor, semi-underground and fully underground sections and stations. This variability allows us to analyse how ventilation conditions and exposure to pollutants can vary depending on the underground or open environment of public transport, as well as the location.

Two types of monitoring have been carried out inside the trains:

- **Targeted on-site monitoring campaigns:** with a duration of one week per season (winter, spring and summer), from 8:00 am to 3:00 pm. The parameters measured include temperature, relative humidity, CO₂, PM2.5, TVOCs, ozone (O₃),



formaldehyde (H_2CO) and nitrogen dioxide (NO_2), with sampling frequencies of between 5 and 1 minute depending on the parameters monitored.

- Continuous monitoring: At the same time, continuous monitoring was carried out by installing sensors in the exhaust grilles of the train ventilation system, also during the three seasonal periods. In this case, the values of temperature (T), relative humidity (RH) and carbon dioxide concentration (CO_2) were recorded continuously with a sampling frequency of 1 minute.

This comprehensive methodological approach provides a detailed insight into the behaviour and variability of pollutants in urban indoor environments, both in buildings and transport, and establishes a solid basis for future strategies to improve indoor air quality.



Figure 28 Measuring devices used inside the metro train.



8.2 Report on action strategies to improve IAQ.

IAQ represents a fundamental aspect of the health, well-being and performance of people in enclosed spaces. In particular, buildings for public use or those occupied by particularly sensitive people - such as children, elderly people, chronically ill people or pregnant women - require special attention in terms of indoor environment management.

Below are a number of strategies and recommendations for maintaining adequate indoor air quality, both under normal conditions and in situations where natural ventilation possibilities are limited.

Recommendations for cleaning work.

Cleaning work can have a significant impact on indoor air quality, especially through the re-suspension of particles and the emission of volatile compounds. To minimise these effects

- Avoid methods that resuspend particulate matter, such as dry sweeping. The use of wet mops or mechanical hoovers is recommended.
- Reduce the use of cleaning products that emit volatile organic compounds (VOCs). If cleaning is necessary, clean when there will be no subsequent prolonged occupancy.
- If cleaning is to be carried out before a period of prolonged use, try to do so with natural ventilation whenever conditions permit.
- Avoid using air fresheners as many emit volatile organic compounds (VOCs).
- Always check the labels of the products you use and avoid those without environmental certifications or containing synthetic fragrances.

Recommendations for effective natural ventilation.

When the ventilation system is equipped with filters - and used correctly, as many buildings have them installed but do not use them or they are not in operation - it will certainly contribute to the improvement of air quality by retaining fine particles and potential pathogens (such as aerosol-borne viruses). However, it is important to underline that air filtering does not reduce the concentration of carbon dioxide (CO₂) and other types of pollutant gases such as ozone (O₃) or nitrogen dioxide (NO₂).



Therefore, although the use of filtered mechanical ventilation can complement biological and physical pollutant control strategies, the only effective way to reduce the levels of these gases is through air renewal, i.e. natural ventilation or forced ventilation with outside air. Natural ventilation can be an effective tool for maintaining good indoor air quality, especially in educational establishments. However, it is important to understand its limitations and its role in relation to other systems.

Key principles for effective natural ventilation

- Cross and distributed ventilation: place openings (windows or doors) on opposite walls and spread throughout the classroom to ensure complete air movement and avoid poorly ventilated areas.
- Continuous ventilation during the use of the space, not only between classes.
- Ventilation of corridors, which directly influence air circulation in adjacent classrooms or offices.
- Adjustment for weather conditions: on windless days or days with similar temperatures inside and outside, it will be necessary to open windows wider to achieve adequate air renewal.

Basic ventilation protocol.

- Keep interior doors open.
- Open windows in cross and distributed configuration.
- Start with a total opening equivalent to a section of 0.80 m².
- Take CO₂ readings until they stabilise.
- Gradually adjust window opening to achieve a balance between ventilation and thermal comfort.

Indoor air management in situations of high occupancy and without the possibility of natural ventilation.

In those periods when the occupancy of spaces is high and natural ventilation is not possible (either due to extreme weather conditions, high outdoor pollution or other constraints), it is recommended:



- Incorporate mechanical ventilation systems with high efficiency filters (such as HEPA or F7/F9, EN ISO 16890:2017) that allow air to be safely renewed, removing particles and pollutants without introducing low quality outside air.
- This measure is especially critical in public buildings and centres with vulnerable people, such as educational centres, hospitals, residences or day-care centres.
- Perform adequate and regular maintenance of ventilation systems, ensuring that they are cleaned, filters are replaced in a timely manner and equipment is working properly.

Use of CO₂ meter.

Carbon dioxide (CO₂) is an excellent indicator of the level of ventilation. To get the most out of this tool:

- Use correctly calibrated analysers located, preferably in the centre of the classroom at a height of more than 1.5 metres, away from direct sources of ventilation or people.
- Wait for the equipment to stabilise before taking readings (5-10 minutes depending on the model).
- Monitor CO₂ levels continuously or at least every 15 minutes to adjust window openings.
- Keep CO₂ levels below 700 ppm, as recommended by the scientific community (such as the Aireamos platform or the Harvard School of Public Health).
 - [Recommended CO2 Levels on the Aireamos Platform](#)

What to do if a CO₂ meter is not available?

In the absence of a CO₂ meter, it is recommended:

- Keep all windows open as long as possible, weather permitting.
- If full opening is not feasible, maintain at least a permanent partial opening and carry out frequent full ventilations.
- Keep in mind that without measurements, you are working blind, and there is an increased risk of CO₂ levels exceeding healthy thresholds, thus increasing the possibility of aerosol transmission of pathogens.



Recommendations in case of poor IAQ.

When poor IAQ conditions are detected - whether due to high CO₂ levels, the presence of pollutants, persistent odours or a feeling of a stuffy atmosphere - it is essential to act quickly to protect the health of occupants. The following are recommended actions:

- Wear facemask: Use facemask to prevent inhalation of airborne contaminants.
 - It is especially important to use it:
 - If you are ill or suspect you are ill, and the disease may be airborne.
 - If you are in a space with vulnerable people (children, elderly, immunocompromised, pregnant, etc.).
 - If you know that there are infectious people in the environment, even if you do not have symptoms.
- Turn on ventilation or ventilate naturally: Turn on the mechanical ventilation system if available and operational. If not available, open doors and windows to promote fresh air intake and indoor air renewal.
- Identify and eliminate the source of pollution. Try to locate the possible source of the pollutants (chemicals, cleaning materials, specific activity, etc.) and remove or isolate it from the common space to avoid further deterioration of air quality.
- In addition to all these recommendations and strategies share the information.
- Communicate what you have learned about air quality with your family, friends and community. Collective awareness-raising is key to generating healthy habits and improving the indoor environment, whether at home, in schools, offices or public spaces.

8.3 Workshops to promote awareness of IAQ and induce behavioural changes to reduce indoor air pollution.

As part of the overall strategy to improve IAQ, a series of workshops and engagement activities have been carried out with the aim of promoting awareness of IAQ issues and encouraging behavioural changes that contribute to the reduction of indoor air pollution. These initiatives have been designed to reach various target groups:

- Session at the II International Workshop on Quality and Environmental Health (November 2023): This event aimed to raise awareness among the public,



This project has received funding from the European Union's Horizon Europe Framework Programme under grant agreement N° 101057497.

professionals, and students about the importance of ensuring appropriate IAQ. It proposes strategies for improvement in both architectural practices and daily habits. This event was open to the public and free of charge. Renowned experts from various fields of knowledge, including medicine, biology, biochemistry, architecture, engineering, and more, specialised in IAQ and health, successfully conveyed and emphasised the importance of IAQ through a multidisciplinary approach in their respective presentations.

- [Session at II International Workshop on Quality and Environmental Health](#)



Figure 29 II International Workshop on Quality and Environmental Health in Seville.

- Workshop entitled “EDIAQ: How can we convert scientific research into effective policies on indoor air quality?” with the featured from Vanda Jakir, Mario Lovrić, Eva Pualusberger, Alex Borg and Samuel Domínguez. The session, attended by over 110 participants, explored how scientific findings can inform impactful IAQ policies. The workshop highlighted the need to bridge the public understanding gap on IAQ, a serious health threat affecting millions annually, particularly given that people in developed countries spend up to 90% of their time indoors.

- [Workshop at Comfort At The Extremes Conference - CATE 2024](#)





Figure 30 EDIAQI Workshop at CATE 2024 in Seville.

8.4 Implementation of data monitoring system open data in Seville with interoperable web services for data visualisation, data access and analysis.

In the framework of the project, the partner KNOW has developed a specific tool that facilitates the uploading of data monitored by the measurement sensors. This functionality has been used by the Seville pilot to incorporate the data in CSV format.

[Access the KNOW Data Platform](#)

CSV Upload UI is a browser-based interactive application that enables users to upload measurements and observations to a FROST server using a simple drag-and-drop interface for CSV files. No prior knowledge of the FROST server or API request syntax is required, making the tool accessible to non-technical users. The application automatically detects and prevents duplicate entries, and it supports uploading observations to multiple Datastreams associated with the same Thing. If temperature values are provided in Fahrenheit, the application automatically converts them to Celsius before uploading.

To handle discrepancies between the uploaded data and the database schema, the application includes a mapping feature that aligns column names from the CSV files with the



corresponding fields in the database. Users can upload one or more CSV files simultaneously.

After the upload, users can verify that the operation was successful. The application provides tools to inspect the most recent observations by timestamp and to detect any missing data.

To prevent anonymous access and unauthorised uploads, the application includes a secure login form. User authentication is managed through Keycloak, which is also used by other applications across the platform to ensure centralised and consistent identity management. The application was implemented in Python, primarily using two open-source libraries: Streamlit and Pandas. Streamlit was used to develop the interactive web-based user interface, enabling features such as file upload, user login, and real-time feedback. Pandas was used for reading, processing, and validating the uploaded CSV files, including tasks like parsing timestamps, handling missing data, and detecting duplicates.

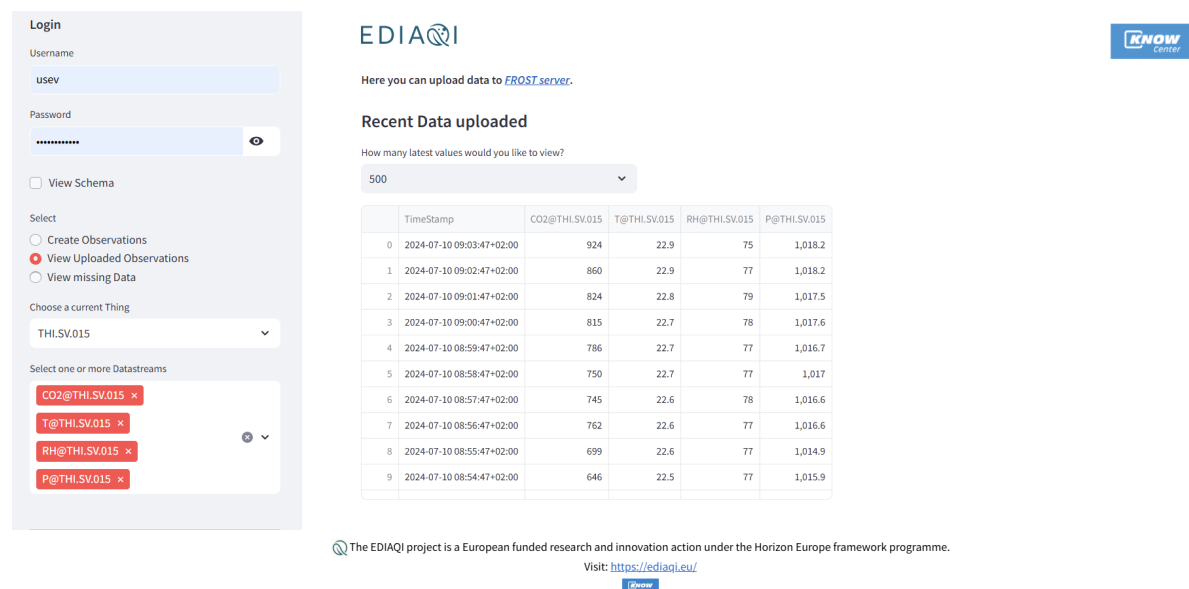


Figure 31 Tool Interface.



9 C3 – Measurement campaign in Vilnius

An intensive air pollution measurement campaign took place in Vilnius, LT, to examine how vehicular pollution affects IAQ in schools. High pollution schools utilised advanced aerosol measurement tools and low-cost sensors to analyse aerosol size distribution, ultrafine particles, and black carbon concentrations. Children wore low-cost sensors to monitor PM_{2.5} exposure in 5-minute intervals during school hours. Additionally, microplastic levels were assessed from collected air samples.

Pilot deliverables:

C3.1 Systematic source apportionment of fine aerosol particles in school environment.

C3.2 Report on determinants of indoor air pollutants in schools in Lithuania.

C3.3 Assessment of exposure of schoolchildren to aerosol particles and microplastics through inhalation.

C3.4 Recommendations to stakeholders on IAQ improvement at schools.

9.1 Systematic source apportionment of fine aerosol particles in school environment.

To identify the sources of fine aerosol particles, black carbon (BC) measurements were conducted both inside a classroom and outdoors on the side of the school facing a nearby motorway. The measurements were performed using micro-Aethalometer MA200 instruments over the period from late November 2023 to May 15, 2024. A nearly two-week gap in January occurred due to the relocation of the entire measurement setup to a neighbouring classroom, prompted by unforeseen circumstances. As a result, the data were analysed in two separate segments, with particular focus placed on the latter measurement period. This second phase was further subdivided into heating and non-heating periods, with April 10, 2024, serving as the transition date. In total, 175 days of BC measurements were collected, 69 days in Classroom C1 and 106 days in Classroom C2. The C2 dataset includes 73 days during the heating season and 33 days during the non-heating season.



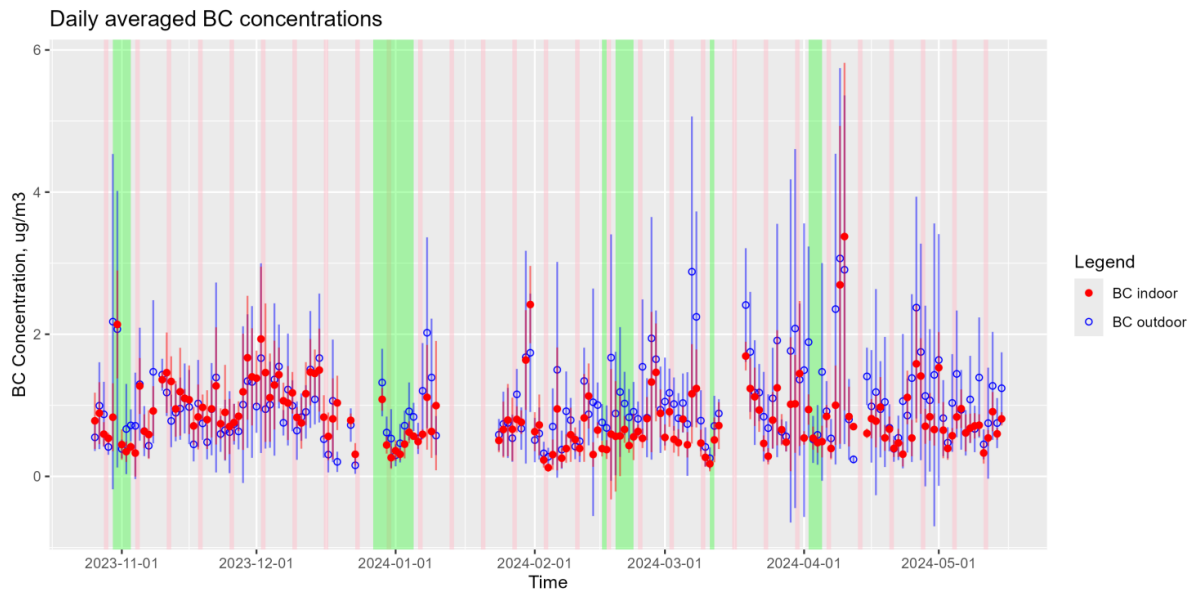


Figure 32 Daily mean BC concentration and its standard deviation in the classroom and outside the school. Pink background - weekend, green - national and school holidays.

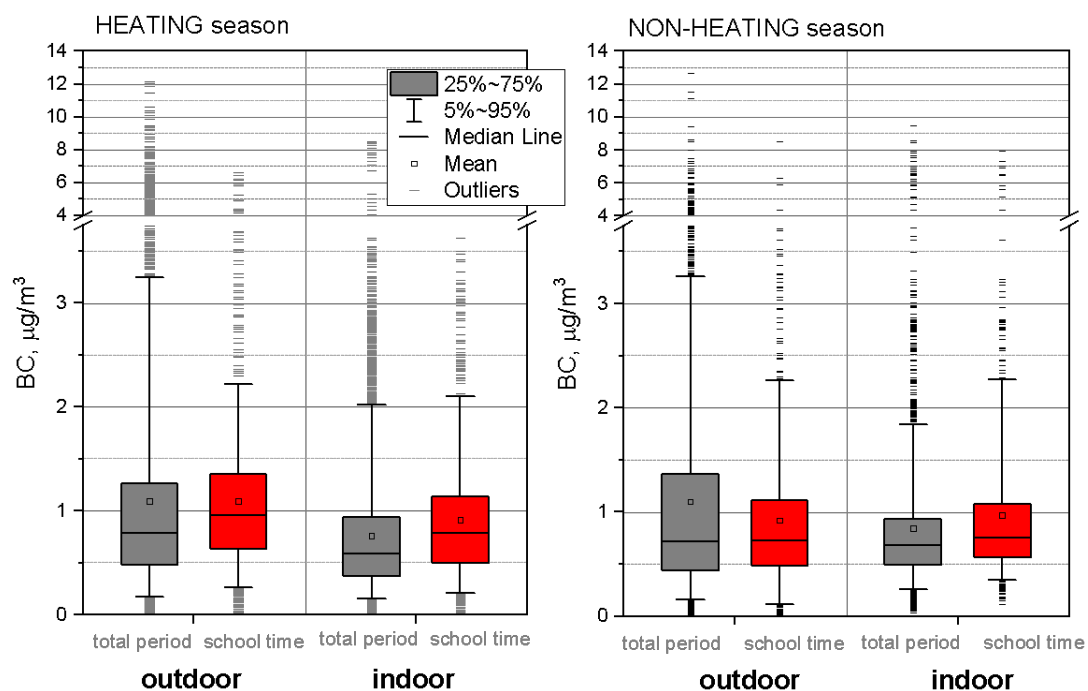


Figure 33 Descriptive statistics of the measured BC concentration in the schoolyard and in the classroom, all measurements (grey box) and school hours (red box, 8:00 - 16:00).

Figure 33 presents a comparative analysis of the BC mass concentrations measured in outdoor and indoor environments during both the heating and non-heating seasons, as well as over the entire period and specifically during school hours. The data reveal greater



variability and more extreme values (outliers), during the heating season, with this effect being more pronounced in the outdoor environment. In general, the mean BC concentrations remained relatively low, ranging from $1.2 \mu\text{g}/\text{m}^3$ outdoor measurements during school hours in the heating season to $0.8 \mu\text{g}/\text{m}^3$ for indoor measurements during school hours in both seasons.

During the heating season, outdoor BC concentrations were consistently higher than indoor levels. However, an increase in indoor median BC concentrations during school hours was observed, suggesting a possible infiltration of outdoor pollutants into the indoor environment. This infiltration may occur through open or poorly sealed windows and doors, particularly when ventilation is increased during occupancy. Additionally, if the trend in elevated BC concentrations aligns with that of particulate matter levels discussed later in this report, it may further support the hypothesis that outdoor pollution is entering the indoor space through multiple pathways.

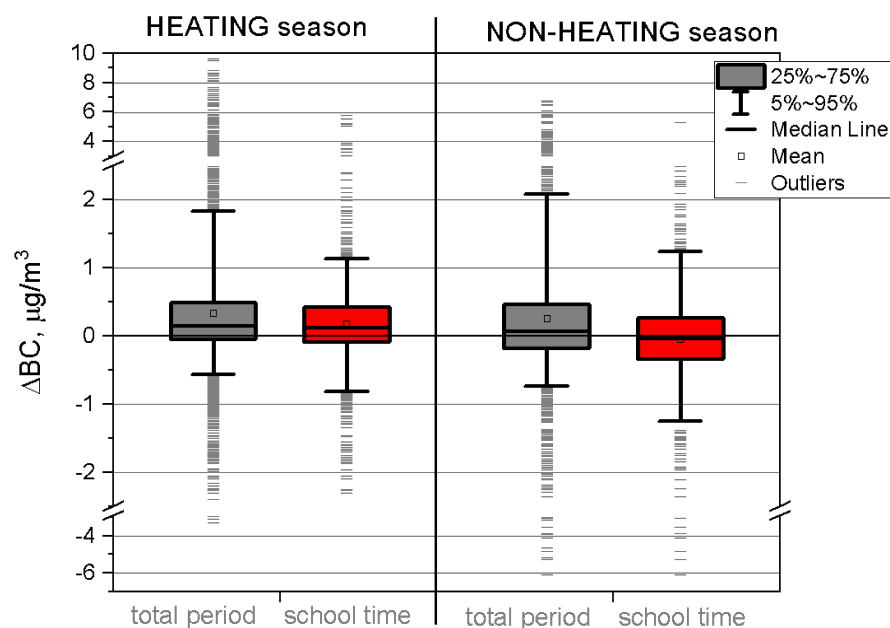


Figure 34 Difference between outdoor and indoor BC concentration during school hours.

Figure 34 shows that the distribution of the difference between outdoor and indoor BC concentration ($\text{BC}_{\text{out}}(t_i) - \text{BC}_{\text{in}}(t_i)$) is quite similar in all analysed cases, even between seasons. However, it is important to note that the difference can be both positive and negative in all cases. This is due to the limited ventilation of the building, which causes the



indoor concentration to react slowly to the increased outdoor concentration (which is a favourable effect), but also to decrease slowly when the outdoor concentration decreases, which is not so favourable. In the case of well-controlled ventilation, the negative part of the statistical distribution of the BC difference should be reduced, so that the number of cases in which the BC concentration is higher indoors than outdoors would decrease. These situations could be avoided if the decision makers had the necessary information about the changes in indoor and outdoor air pollution in time.

A substantial fraction of the total black carbon (BC) concentration measured both outdoors and indoors was attributed to fossil fuel combustion or transport-related sources, reaching up to 85% of the total BC Figure 35. This high contribution is likely due to the school's proximity to an urban motorway with intense traffic volumes, which serves as a continuous and dominant emission source in the area.

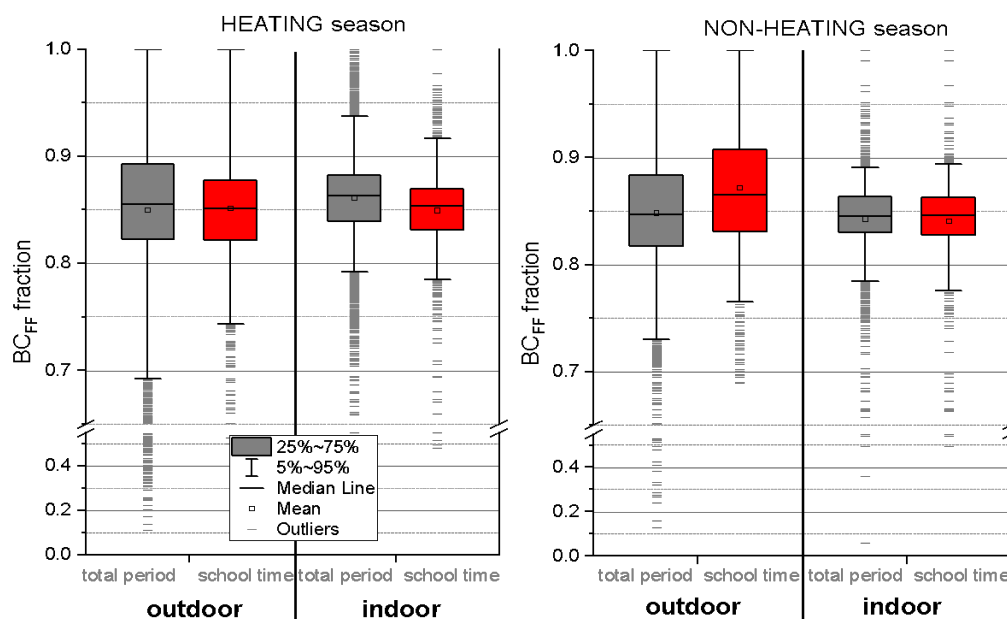


Figure 35 Descriptive statistics of the black carbon related to the transport on the schoolyard and in the classroom, all measurements (gray box) and school hours (red box, 8:00 - 16:00).



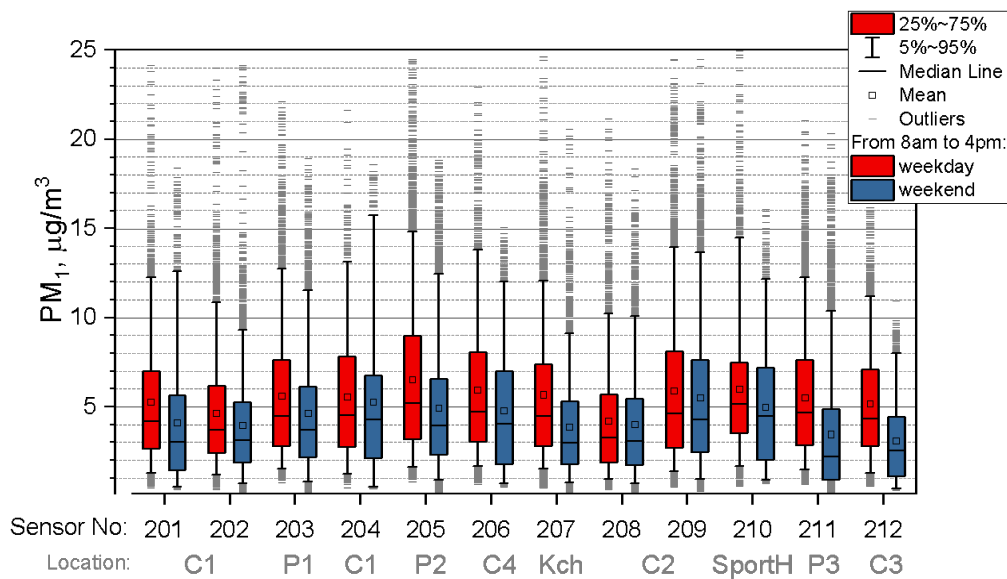


Figure 36 PM₁ concentrations in school during school hours compared to weekends in heating season.

Figure 36 presents the concentrations of PM₁ concentrations at various locations within the school during school hours (8 am to 4 pm) on both weekdays and weekends throughout the heating season, using data from the AirWings sensors. The data were collected using AirWings sensors installed in three classrooms, three corridor locations, as well as in the school canteen and sports hall. Weekend median PM₁ concentrations ranged between 3.4 and 4.0 µg/m³, representing the baseline indoor air quality in the absence of occupancy and activity. The greatest difference between weekday and weekend concentrations was observed for corridor sensor P3 and classroom sensor C3, both located on the side of the school not directly facing the busy street. During school hours on weekdays, classroom PM₁ median concentrations ranged from 4.7 to 5.5 µg/m³, depending on the specific room (C1–C4). In comparison, PM₁ concentrations in the corridors were generally higher than those in the classrooms, with medians ranging from 4.9 to 6.8 µg/m³. The highest mean and median PM₁ concentrations during school hours were recorded by corridor sensor P2, which is positioned near the main school entrance, registering a median of 6.8 µg/m³. PM₁ concentrations measured in the school canteen during weekdays were comparable to those at other indoor locations, indicating effective ventilation and/or efficient containment of cooking-related particulate emissions within the designated kitchen area.



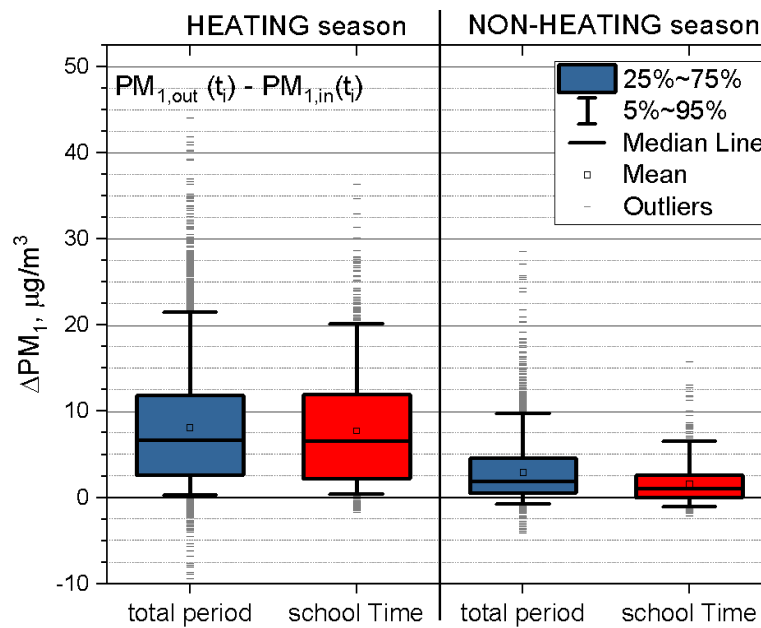


Figure 37 Box plot of difference between PM_1 concentrations in school (class C1) and outdoor environments during two seasonal periods.

A comparison of PM_1 concentrations between the indoor environment (Class C1) and the outdoor environment across two seasonal periods (heating and non-heating) and two timeframes (total period vs. school hours) reveals that mean and median values do not differ significantly between the total period and school time within each season. However, a slightly lower median and mean PM_1 difference (outdoor minus indoor) was observed during school hours in the non-heating period, suggesting improved ventilation conditions. This finding is consistent with the common practice of keeping windows open for longer durations during the warmer season, which likely enhances air exchange and reduces indoor particulate accumulation relative to outdoor levels. However, this also means that the concentration of particulate matter outside the school has a greater influence on the concentration of particulate matter inside the school, especially during the non-heating period and during school hours, i.e. a higher concentration of particulate matter outside the school penetrates more quickly into the interior of the school.



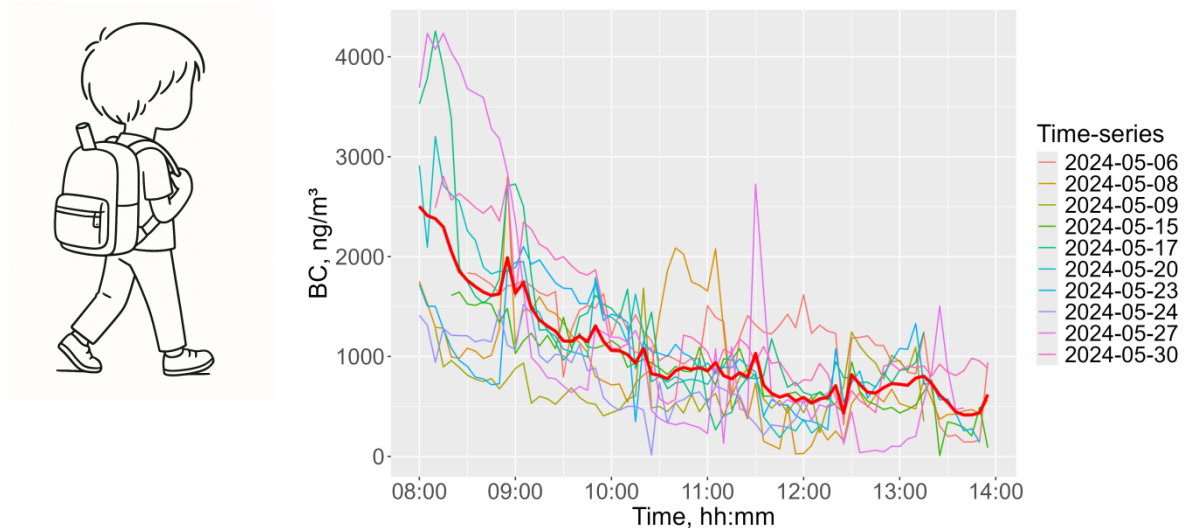


Figure 38 Left image: Illustrative picture of a student carrying the MA200 device. Right figure: Black carbon concentrations (in ng/m^3) during the day (from 08:00 to 14:00).

Black carbon measurements were conducted over a ten-day period using a portable MA200 micro-Aethalometer carried in a backpack during school hours. A distinct morning peak in BC concentrations, typically occurring between 08:00 and 09:00, was observed on most days. During this period, BC levels occasionally exceeded 3,000–4,000 ng/m^3 , indicating the presence of strong emission sources. Given that these measurements were conducted during the non-heating period, the elevated morning concentrations are likely attributable to traffic-related emissions, particularly from morning rush-hour vehicle activity near the school. Following this peak, a gradual decline in BC concentrations was consistently recorded between 09:00 and 12:00, with the mean trend line clearly reflecting this downward pattern. This suggests a reduction in exposure intensity as traffic volume decreases and classroom conditions stabilise during the late morning hours. After midday, BC concentrations stabilised with some variability in BC values between days and the mean BC concentration dropped below 1000 ng/m^3 . The variability of the BC concentration during the day could be due to an uneven distribution of the BC concentration in the school. The inter-day variability is influenced by outdoor BC concentrations, which was described above. In general, the BC data showed a typical urban pollution pattern, with high BC concentrations in the morning due to intense BC emissions, followed by a decreasing trend.

9.2 Report on determinants of indoor air pollutants in schools in Lithuania.

Data were collected between late November 2023 and May 2024 in a representative urban school located near a busy motorway in Vilnius. The pollutants analysed included black carbon (BC), PM₁, aerosol particle number and mass concentrations, and airborne microplastics (MPs). Measurements were conducted during both heating and non-heating seasons and during school and non-school hours to identify temporal and spatial variation patterns.

Black carbon as an indicator of combustion sources

BC measurements using MA200 aethalometers revealed that outdoor BC levels were generally higher than indoor levels during the heating season, with median indoor values increasing during school hours, suggesting both outdoor infiltration and occupancy-related indoor sources. Outdoor contributions reached up to 85% of total BC, attributed to traffic emissions from the adjacent motorway. Notably, peak concentrations occurred in the morning (08:00–09:00) and then declined steadily throughout the day, showing a typical urban pollution profile. The data also revealed that limited ventilation contributed to occasional instances where indoor BC exceeded outdoor levels, particularly when outdoor concentrations had recently dropped.

Particulate matter (PM₁) and human activity

PM₁ concentrations, measured using AirWings sensors, were consistently higher on weekdays compared to weekends, with weekday medians in classrooms ranging from 4.7 to 5.5 µg/m³ and corridors showing higher levels (up to 6.8 µg/m³), particularly near entry points. Weekend concentrations (3.4–4.0 µg/m³) reflected baseline conditions with minimal human activity. These results indicate that occupancy and movement are key drivers of indoor PM₁ levels. Interestingly, PM₁ concentrations in the canteen were comparable to other rooms, suggesting effective containment of kitchen emissions through localised ventilation. Seasonal comparison showed no drastic differences in indoor vs. outdoor PM₁ concentrations between total daily periods and school hours. However, during the non-heating season, improved ventilation (e.g., open windows) resulted in a smaller difference



between outdoor and indoor concentrations, suggesting faster equilibration between environments and more direct influence of outdoor air quality on indoor conditions.

Aerosol particle number concentration and size distribution

Fine aerosol particle number concentrations (300–10,000 nm) were assessed using a combination of MPSS, OPS, APS, and CPS instruments. Smaller particles (300–800 nm) dominated the number concentrations across all time periods, especially during school hours. Larger particles (800–10,000 nm) contributed more significantly to mass concentrations, particularly during school hours, reflecting resuspension or activity-related generation. The number concentration of larger particles increased unexpectedly during weekends, despite lower occupancy, suggesting a need for further investigation into cleaning schedules, ventilation behaviour, or resuspension mechanisms. These data also emphasise the importance of differentiating between number- and mass-based exposure assessments, as each highlights different pollutant dynamics.

Airborne Microplastics

Indoor MPs levels (mean: 4,127 MPs/m²/day) were slightly higher and more variable than outdoor levels (mean: 3,533 MPs/m²/day), with peaks observed during high-activity periods. Indoor concentrations were dominated by fibres and fragments originating from textiles (31%), packaging (30.6%), and flooring materials (17.3%). Chemical analysis revealed that polyester (33%) and acrylates (31.1%) were the most common polymers indoors, associated with synthetic fabrics, coatings, and furnishings.

In contrast, outdoor MPs were dominated by polyethylene (48.6%), consistent with plastic debris and packaging degradation. MPs from transport-related sources (e.g., tire wear, road dust) were identified through the prevalence of black particles and rubber-based polymers, accounting for up to 28% of the outdoor MP load.

MP source attribution

A comparative analysis of airborne MP sources in indoor and outdoor environments reveals distinct profiles, driven by differences in human activity, environmental exposure, and material degradation processes. In the indoor environment, the largest share of MPs was attributed to textile-related sources, accounting for 31% of the total. This predominance is



consistent with the known shedding of synthetic fibres from clothing, upholstery, curtains, and carpets. The nature of indoor spaces facilitates the accumulation and suspension of textile fibres in the air. Packaging materials contributed 30.6%, likely originating from the handling and degradation of plastic containers, bags, and wrappers frequently used and stored indoors. Notably, this category exhibited the greatest variability among all sources (range = 14.2%), with peak contributions aligning temporally with elevated fragment abundance and higher proportions of PP and PE. This suggests that packaging-derived MPs are episodically released, likely influenced by daily activities such as handling or unpacking plastic materials. MPs derived from flooring materials represented 17.3%, suggesting a significant contribution from abrasion of plastic-based floor coverings, composite panels, and sealants. Higher values in samples were enriched with PVC, rubber-based polymers, and larger particle size classes ($>500\text{ }\mu\text{m}$). This reflects potential inputs from surface abrasion of vinyl flooring, rubber mats, or foot traffic-induced resuspension of settled debris. While the average contribution was the lowest among all sources, the observed range (13.9%–21.4%) suggests that flooring may act as an episodic reservoir for MP release. Notably, outdoor-derived particles constituted 21.1%, indicating the infiltration of microplastics from the external environment through ventilation systems, open windows, or via occupants.

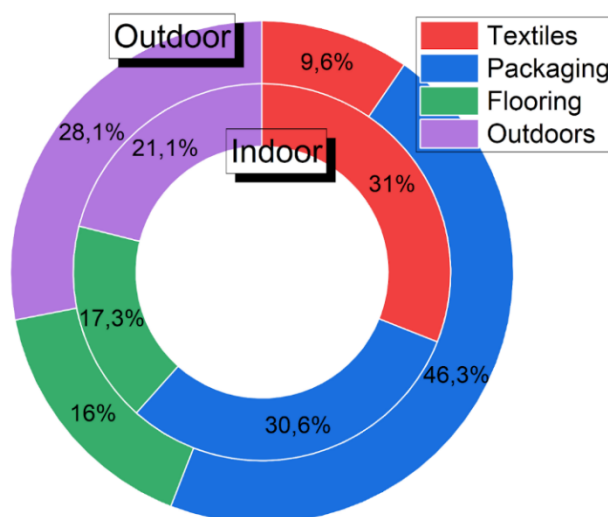


Figure 39 Microplastic Source Attribution Map

The outdoor microplastic source attribution analysis revealed a markedly different source profile compared to indoor environments. The outdoor MP profile was dominated by



packaging-related sources, which comprised 46.3% (from 40.4% to 66.0%) of the total, primarily driven by high levels of PE and PP fragments. This reflects the widespread environmental dispersion of fragmented plastic debris such as bags, films, and containers subjected to weathering, UV degradation, and mechanical breakdown. MPs of outdoor origin, including those from road dust, tire wear, and soil-bound fragments, represented 28.1% (from 21.4% to 30.9%), emphasising the influence of urban infrastructure and vehicular activity. This category was strongly associated with black coloration, large fragments, and rubber-based polymers such as polyisoprene and synthetic rubbers. Flooring-related MPs, potentially arising from wear of outdoor surfaces or construction materials, accounted for 16% (from 9.5% to 20.0%). Although indoor floors are unlikely to be a direct outdoor source, urban analogues such as painted façades, outdoor linings, or degraded construction materials may contribute similar particles. Textile-derived MPs made up only 9.6% (from 3.1% to 11.6%) of the total, substantially lower than indoors, which supports the hypothesis that textile fibre emissions are predominantly localised within enclosed environments. These values are consistent with expectations that synthetic textile fibres, while abundant indoors, are far less prevalent or persistent in the more turbulent and diluted outdoor air environment.

9.3 Assessment of exposure of schoolchildren to aerosol particles and microplastics through inhalation.

Aerosol particles

To evaluate the differences in the number concentrations of fine aerosol particles during school hours indoors and outdoors, simultaneous measurements were conducted in a classroom and outdoors on the side of the school facing a motorway. The instruments used included a Mobility Particle Size Spectrometer (MPSS), Aerodynamic Particle Sizer (APS), Optical Particle Sizer (OPS), and Condensation Particle Sizer (CPS). The measurement campaign was carried out from late November 2023 to May 15, 2024. Due to technical issues, outdoor measurements were limited to the period from January 24 to May 15, 2024, while indoor measurements spanned the entire campaign period. In total, 165 days of indoor MPSS data were collected—55 days in Classroom C1 and 110 days in Classroom C2—



including 36 days during the non-heating period. For the outdoor environment, 59 days of MPSS data were obtained, all during the heating period. These measurements provide a comprehensive basis for assessing particle number concentrations and evaluating indoor–outdoor relationships across different seasonal and spatial contexts.

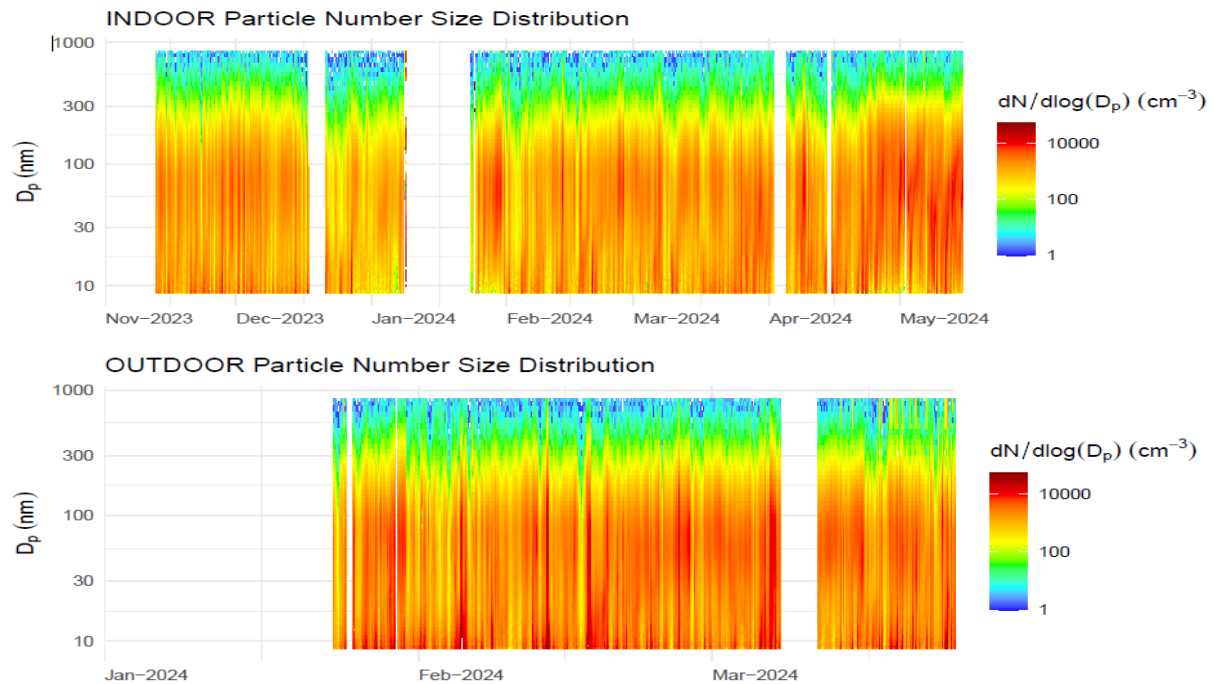


Figure 40 Particle number distribution by particle size in the class and outdoors.

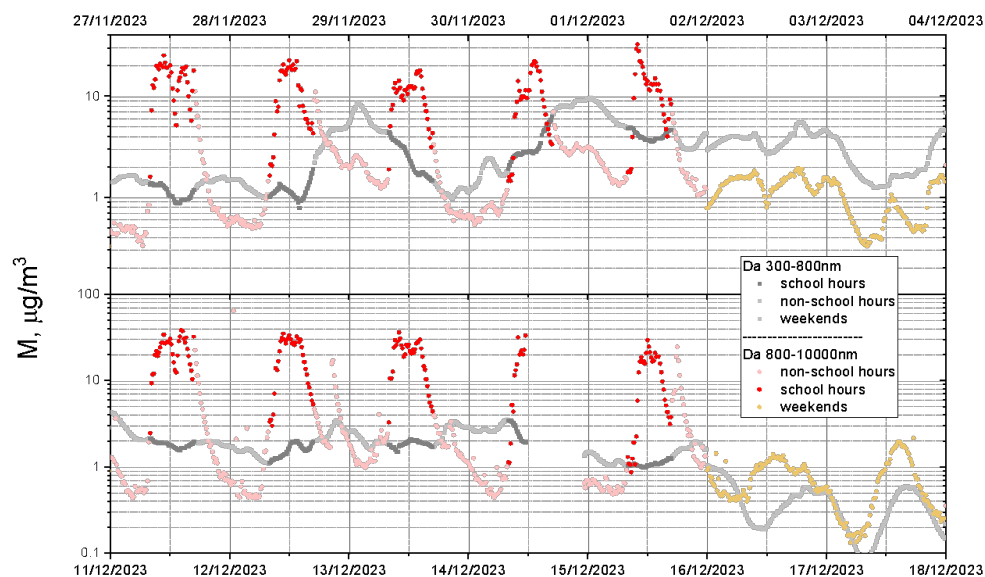


Figure 41 Time series of mass concentration of aerosol particles in the class.



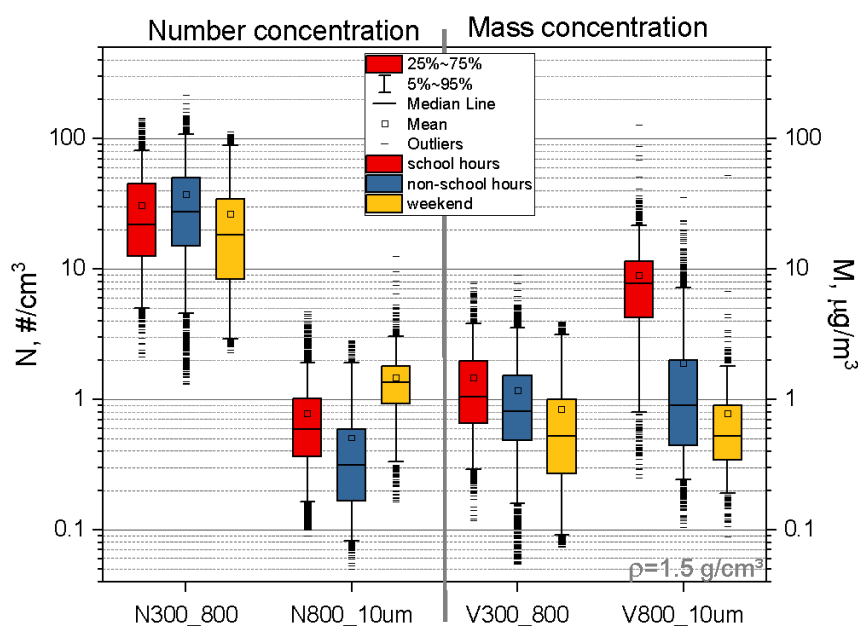


Figure 42 Boxplots comparing the number concentration (left panel) and mass concentration (right panel) of aerosol particles.

The number concentration of airborne particles with aerodynamic diameters ranging from 300 nm to 10 µm was measured using OPS instruments. For indoor measurements, air from the school classroom was directed via tubing into a mobile laboratory van equipped with the measurement devices, which was stationed outside the school building. Total particle number and volume concentrations were calculated for two defined size modes based on aerodynamic diameter: (i) smaller particles in the range of 300–800 nm, and (ii) larger particles ranging from 800–10,000 nm. The volume concentrations were estimated by assuming a particle density of 1.5 g/cm³. These data are presented in Figure 40 and provide insight into the size-resolved distribution of aerosol particles in the school environment. Figure 41 illustrates that smaller particles (300–800 nm) consistently exhibit the highest number concentrations across all time periods, including school hours, outside school hours, and weekends. The lowest median value (0.3#/cm³) of the number concentration indoors was determined for larger particles, the highest median value (25 #/cm³) was obtained for smaller particles, both during non-school hours. This difference between medians also illustrates the consistent drop in number concentration moving to the larger particle size



range. Number concentration during school hours was close or larger than during non-school hours for smaller and larger particles, respectively. This could be explained by the slower deposition of smaller particles. However, the increase in the concentration of larger particles during the weekend is unexpected and needs to be investigated.

The mass concentration of larger particles was significantly higher than that of smaller particles, which is to be expected as the volume scales with the particle diameter in the cube. The mass concentration at the weekend was lowest in both size ranges. The mass concentrations during school hours are significantly higher for larger particles, i.e. large particles contribute more to the particulate matter concentration during school hours. As the number concentration of larger particles is highest at weekends compared to the other periods and the mass concentration is lowest, this indicates that the size distribution should be different compared to the other periods and this needs to be analysed.

Microplastics MPs

To estimate the relative contribution of different indoor sources to airborne MPs, a semi-quantitative source attribution model was developed based on particle composition and physical characteristics. The approach aimed to differentiate MPs originating from major indoor categories: Textiles, Packaging, Flooring, and Outdoors. The model utilised measured parameters including particle polymer type, shape (fibres and fragments), colour, and size distribution. These features were selected due to their established associations with specific material types and environmental behaviours. For example, PES and PA are typically linked to textile shedding, while PP and PE are widely used in packaging materials. Polymers such as PVC, rubber compounds, and PS were linked to flooring, insulation, and building materials. Black and red particles, often derived from tire wear and external sources, were used to represent outdoor contributions. Each feature was assigned a set of relative weightings (ranging from 0 to 1) indicating its likelihood of originating from each of the four source categories. These weights reflected the probability that a given feature originated from a particular source and were based on empirical data and material usage patterns reported in previous studies. For instance, PES and fibres were assigned high weights for the textile category, while black particles and rubber-based polymers were primarily attributed to outdoor or flooring-related sources. A complete matrix of feature-to-source weights was



constructed and uniformly applied across all samples. For each sampling date, the measured relative abundance of each feature was multiplied by its corresponding source weights. The resulting values were aggregated per source category to produce a raw source contribution score. These scores were then normalised such that the total contribution across all sources summed to 100%, yielding an estimated percentage contribution from each source category for each sample (Table 12).

Table 12 Feature-to-Source Weight Matrix

Feature	Textiles	Packaging	Flooring	Outdoors
Polyester	1.0	0.1	0.0	0.0
Polyamide	0.1	0.3	0.3	0.3
Polypropylene	0.2	1.0	0.2	0.1
Polyimide	0.1	0.2	0.3	0.4
Polyethylene	0.1	1.0	0.1	0.2
Polyvinylchloride	0.0	0.2	1.0	0.2
Polystyrene	0.0	0.5	0.3	0.2
Rubbers	0.0	0.1	0.4	1.0
Polyisoprene	0.0	0.1	0.3	1.0
Nitrile butadiene rubber	0.0	0.2	0.5	0.3
Acrylates	0.3	0.5	0.2	0.0
Fibers	1.0	0.0	0.0	0.0
Fragments	0.0	1.0	0.3	0.3
Black	0.0	0.2	0.2	1.0
Red	0.1	0.3	0.2	0.4
Blue	0.3	0.4	0.2	0.1
Green	0.2	0.3	0.3	0.2
<50 µm	0.6	0.3	0.2	0.3
50–100 µm	0.5	0.4	0.2	0.3
100–250 µm	0.4	0.5	0.3	0.2
250–500 µm	0.3	0.5	0.4	0.2
500–1000 µm	0.2	0.5	0.5	0.3
>1000 µm	0.1	0.4	0.6	0.4

This approach enabled identification of background emissions (e.g., persistent textile shedding) as well as episodic inputs, such as packaging- or flooring-related fragments, and periods potentially influenced by outdoor infiltration.

Inhalation Risk based on MPs composition

To assess the relative health relevance of detected airborne MPs, a simplified inhalation risk index was calculated for both indoor and outdoor samples. This index integrated two key factors influencing potential respiratory impact: polymer toxicity and particle morphology.



Each detected polymer was assigned a toxicity weighting ranging from 0 (low concern) to 1 (high concern) based on REACH databases.

For each sample, the index was calculated as:

$$IRI = \sum_{i=1}^n (A_i \cdot W_i) \quad , \quad [1]$$

where:

A_i - Relative abundance (%) of feature i (polymer or shape)

W_i - Weight assigned to feature i based on known or suspected inhalation hazard

PVC received the highest score (1.0) due to its chlorine content, phthalate plasticizers, and potential to release toxic combustion products. Rubber-based polymers (e.g., PIR, nitrile rubber) were similarly weighted high (0.9) due to their known content of carcinogenic polycyclic aromatic hydrocarbons (PAHs), heavy metals, and vulcanisation agents.

Moderate-risk polymers such as ACR and PS were assigned intermediate scores (0.7), while relatively inert polymers like PE and PP were weighted lower (0.3–0.4). In addition to polymer identity, particle morphology was incorporated by assigning elevated risk to fibrous MPs (weight = 0.9) due to their greater likelihood of deposition in the lower respiratory tract compared to fragments (weight = 0.5). The final risk score for each sample was computed as the sum of polymer- and shape-weighted abundances, normalised to provide a unitless inhalation risk index.

MP amount indoor and outdoor

Statistical analysis of MPs concentrations in indoor and outdoor environments has revealed significant differences in their distribution and variability. On average, indoor MP levels are slightly higher than outdoor levels, with mean and median values of 4,127 and 3,851 MPs/m²/day indoors, compared to 3,533 and 3,313 MPs/m²/day outdoors, respectively. While the range of outdoor MP levels is comparatively narrower (approximately 1,352 to 6,236 MPs/m²/day), those in the indoor environment exhibit a significantly wider range (approximately 754 to 7,933 MPs/m²/day). The standard deviations further emphasise this contrast, with $\sigma = 1,731$ for outdoor samples and $\sigma = 2,556$ for indoor samples, highlighting the dynamic and location-dependent nature of the presence of microplastics in both environments. The lowest concentration was observed on December 11-25, 2023 (753



MP/m²/day), coinciding with the winter holiday period, when indoor activity and human occupancy were presumably reduced. In contrast, the maximum concentration was recorded on March 4-11, 2024, reaching 7933 MP/m²/day, suggesting a substantial short-term input of microplastics, potentially linked to intensive indoor activity, resuspension, or external intrusion (e.g., open windows or cleaning events). This variation suggests the possibility of seasonal fluctuations in microplastic pollution.

The chemical characterisation of MPs revealed a heterogeneous mixture of polymer types indoor, reflecting diverse material sources and usage patterns within enclosed spaces. Among the identified polymers, PES was consistently dominant indoors, comprising 33.0% of all analysed particles. (Fig. 3.3.4). Acrylates followed closely at 31.1%, together accounting for 64.1% of indoor MPs. These polymers are commonly associated with synthetic textiles, furniture coatings, and household products, suggesting that indoor sources are largely driven by human activities, including fabric abrasion, material degradation, and the use of treated surfaces. PE, although dominant outdoors, accounted for only 16,0% indoors. The presence of nitrile rubber (6,7%) further supports the influence of indoor-specific sources such as flooring materials, gloves, or sealants. The presence of PP (3.8%), PS (4.7%), and smaller amounts of polyisoprene (2.8%) and PVC (1.9%) further supports a range of indoor-specific sources including flooring materials, packaging, sealants, and textiles.



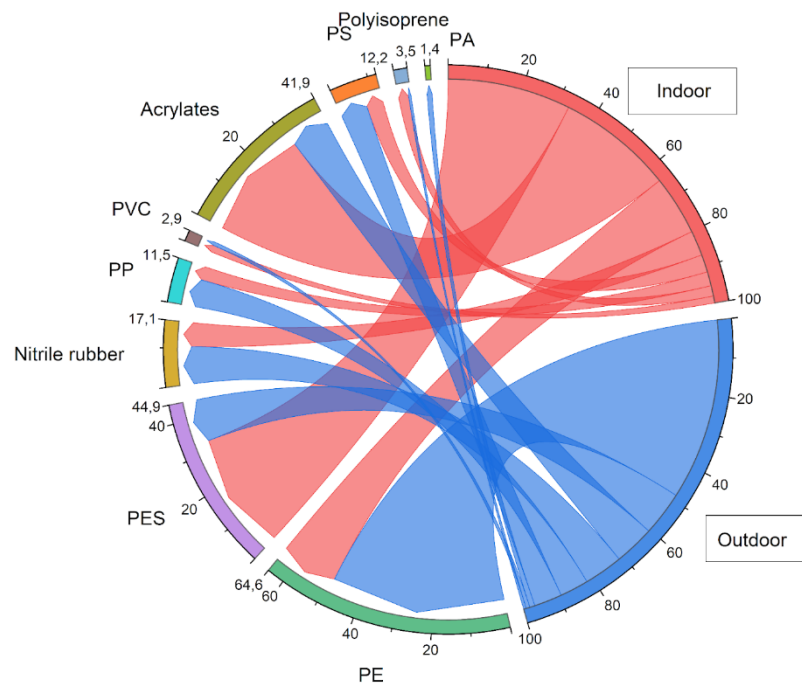


Figure 43 Chemical composition of MPs indoors and outdoors

In contrast to indoor air, the outdoor environment was characterised by a strong dominance of PE, comprising ~48.6% of the total detected MPs. This prevalence is likely attributable to the widespread environmental degradation of plastic packaging, bags, and other polyethylene-based debris. Other notable polymers identified in the outdoor air included polyester (PES, 11.9%), acrylates (10.8%), and nitrile rubber (10.4%), suggesting additional contributions from airborne textile fibres, weathered paints or coatings, and traffic-related sources. Furthermore, polymers such as PP (7.7%), PS (7.5%), PA (1.4%) and PVC (1.0%) were observed in higher relative proportions in outdoor samples compared to indoor environment. These differences may reflect the impact of environmental weathering, atmospheric transport, and exposure conditions on polymer fragmentation and persistence.

9.4 Recommendations to stakeholders on IAQ improvement at schools.

Establish regular indoor–outdoor air quality monitoring

- Implement continuous or periodic monitoring of indoor and outdoor air quality using calibrated low-cost sensors for fine particulate matter (PM₁ or PM_{2.5}) and black carbon (BC). Real-time or near-real-time data can be used to trigger alerts, optimise



cleaning schedules, and coordinate building maintenance activities based on pollution levels.

- Create a centralised data dashboard to visualise and compare indoor and outdoor air quality trends over time. This can support early identification of problem areas, evaluation of mitigation strategies, and communication with school staff, students, and parents.

Improve source awareness and behaviour among school staff and students

- Perform seasonal comparisons and source analysis to understand the impact of heating, traffic patterns, and school-specific sources on indoor pollution. Use this information to prioritise interventions during high-exposure periods (e.g., heating season, morning traffic peaks).
- Provide targeted education for teachers and staff on the typical patterns of air pollution infiltration, with a focus on identifying peak exposure times—for example, elevated concentrations of BC and PMs commonly occur between 8:00 and 9:00 a.m. due to increased traffic activity.
- Engage students and staff in citizen science initiatives by involving them in air quality data interpretation, classroom discussions, and school-based monitoring projects. This participatory approach fosters environmental awareness, encourages proactive behaviour, and builds a shared responsibility for maintaining healthy indoor environments.
- Display air quality information visibly within the school, such as on digital monitors or posters showing real-time sensor data and guidance for safe ventilation practices.
- Incorporate air quality topics into the school curriculum through interdisciplinary learning, linking science, health education, and environmental studies. Hands-on projects, such as indoor–outdoor air quality comparisons or microplastic sampling, can build awareness and critical thinking skills.

Optimise ventilation strategies according to season and outdoor air quality.

- Install CO₂ and PMs sensors in classrooms to enable real-time monitoring of indoor air quality. These sensors can inform adaptive ventilation decisions, such as when to



open or close windows, balancing the need for fresh air with the goal of minimising infiltration of outdoor pollutants.

- Adjust window ventilation practices to align with periods of lower outdoor air pollution. Specifically, encourage window airing during late morning or early afternoon hours, and avoid opening windows during morning rush hours to minimise the ingress of traffic-related pollutants.
- Regulate the operation of open/close windows, particularly during the heating season, to reduce the intake of BC and fine PM associated with vehicular emissions. Emphasis should be placed on avoiding ventilation during peak outdoor pollution periods.
- During the non-heating season, when natural ventilation (e.g., open windows) is more common, implement additional protective measures such as air filtration systems or window-mounted vent filters. These solutions can effectively reduce the penetration of outdoor pollutants and help maintain healthier indoor air quality levels.

Reduce indoor resuspension and source contributions

- Implement regular cleaning protocols in indoor high-traffic areas, such as corridors and entrance zones, using low-resuspension methods. Wet mopping and vacuuming with HEPA-filtered equipment are recommended to effectively capture PM and reduce the re-suspension of settled pollutants.
- Minimise the use of synthetic flooring and furnishings known to shed microplastics—especially materials made from polyvinyl chloride (PVC), acrylates, and rubber-based composites. When selecting materials for renovations or new installations, prioritise low-emission, natural alternatives such as linoleum, wood, or cork.
- Encourage the use of natural textiles and sustainable materials in classroom furnishings, window treatments, and storage solutions. Discourage reliance on excessive plastic packaging, containers, and commonly used school supply items (e.g., plastic folders, bins), which can degrade over time and contribute to microplastic accumulation indoors.



Monitor and manage high-risk indoor sources of microplastics

- Replace heavily worn synthetic flooring and soft furnishings in classrooms with low-shedding or natural alternatives, such as wool, cotton, linoleum, or untreated wood, to minimise ongoing microplastic emissions resulting from mechanical wear and material degradation.
- Assess and progressively substitute plastic-based stationery items (e.g., plastic pens, mechanical pencils, rulers, and binders) that are prone to fragmentation or surface abrasion, particularly those exhibiting visible wear. Prioritise the use of more durable, reusable, or biodegradable materials to reduce indoor microplastic generation.
- Minimise exposure to airborne microplastics from stored materials by placing plastic packaging, classroom supplies, and other high-friction items in closed cabinets or separate storage rooms. This reduces the risk of particle release through mechanical abrasion, thermal stress, or material breakdown.
- Raise awareness about clothing as a source of fibre-based microplastics, particularly garments made from synthetic materials such as polyester, nylon, and acrylic. Encourage the use of natural fabrics (e.g., cotton, wool) for uniforms and indoor wear.



10 C4 – Awareness campaigns

Raising environmental awareness is crucial for reducing outdoor and indoor air pollution. EDIAQI launched an awareness campaign targeting children and their families involved in pilot studies as well as a broader public from several EU countries. A questionnaire was created to assess participants' knowledge about health-related issues regarding IAQ. This enables a critical evaluation of public information sources and offered a possibility to address disparities in awareness. The findings on participants' attitudes toward IAQ and its health impacts will help develop guidelines and training materials, promoting health and disease prevention across different sectors and socio-economic settings while enhancing overall environmental health awareness.

Pilot deliverables:

C4.1 Questionnaire on air pollution and related health risk.

C4.2 Report on results obtained from awareness campaigns.

10.1 Questionnaire on air pollution and related health risk.

The EDIAQI project implemented a robust and multi-layered methodology to evaluate public awareness of indoor air quality (IAQ) and its associated health risks. Central to this approach was the development and deployment of two comprehensive surveys: a long-form questionnaire and a short-form version, each tailored to different audiences and research contexts.

The long-form IAQ awareness questionnaire was specifically designed to gather in-depth information and was conducted within a pilot study in Zagreb, Croatia. This survey targeted a cohort of 129 parents of 179 children, including both children with asthma or allergies and healthy controls, aged between 5 and 18 years. The aim was to assess IAQ awareness in households where children with respiratory problems reside and compare obtained answers with the healthy control group. The questionnaire was distributed in two formats—paper-based versions during household visits and an online format—allowing for flexibility in participation. Data collection for this long-form survey spanned from May 2023 to December 2024. The questionnaire covered five thematic domains. The first focused on socio-demographic characteristics of the participants, including age, gender, education



level, occupation, income, household composition, and living environment (urban or rural). This helped contextualise the responses and identify trends across different social groups. The second section addressed participants' knowledge of indoor air pollution, examining their understanding of pollutants such as radon, volatile organic compounds from plastics and cleaning agents, and the importance of humidity and ventilation. The third domain explored behavioural patterns related to IAQ, such as how often households ventilated rooms—especially during winter months—whether they used eco-friendly cleaning products, and how regularly they maintained air-conditioning systems and heating devices. The fourth domain assessed attitudes towards indoor air pollution, including willingness to invest in products that improve air quality and beliefs about personal control over household air environments. Lastly, the survey gathered self-assessments of household members' quality of life and general health, including perceptions of the risks posed by both indoor and outdoor air pollution.

Additionally, a shorter version of the questionnaire was developed to reach a broader and more diverse sample across Europe. This short-form questionnaire retained the core thematic structure of the long version—covering knowledge, behaviours, and attitudes—but was streamlined for wider dissemination. It was collaboratively developed by EDIAQI partners and implemented as an online survey using the EU Survey tool. The questionnaire was translated into five languages and distributed across five countries: Estonia, Italy, Lithuania, Croatia, and Spain. The survey was conducted between March and May 2024 and yielded a total of 703 responses. While this wider reach provided valuable cross-country comparisons, it is important to note that the sample was not entirely balanced. Italian and Croatian participants made up the majority of respondents, and approximately half of the overall sample consisted of high school students, particularly due to the involvement of schools in the Ferrara pilot in Italy. The age distribution was therefore bimodal, with one group averaging around 16 years of age and the other averaging 41 years. Despite these sampling limitations, the short-form survey offered key insights into public perceptions and behaviours related to IAQ across different age groups, education levels, and countries. It revealed, for example, that a significant portion of respondents—particularly among youth—had limited awareness of indoor air pollutants and did not routinely engage in



behaviours known to improve IAQ, such as regular ventilation during winter or the use of non-toxic household products. The survey also highlighted gender differences, with women generally scoring higher in IAQ knowledge, attitudes, and behaviours. This aligned with existing research suggesting that women may be more attuned to environmental health issues. Notably, while educational level appeared to influence attitudes slightly, it did not have a strong impact on knowledge or behaviour, indicating the need for targeted awareness efforts even among well-educated populations.

Overall, the methodological approach of the EDIAQI project—combining the depth of localised data from the long-form survey with the breadth of regional insights from the short-form version—provided a comprehensive picture of IAQ awareness across Europe. These surveys were instrumental in identifying critical knowledge gaps, such as low awareness of radon and the health impacts of household materials and poor ventilation. The findings were used for the design of tailored educational materials for children, adolescents, and adults, and shaped public engagement strategies, including workshops, webinars, and social media campaigns.

A more detailed report can be found in the D5.5. deliverable (“Report for presenting a novel method for assessing air pollution and building related health risk awareness based on qualitative research”).

10.2 Report on results obtained from awareness campaigns.

The EDIAQI project successfully demonstrated a novel, research-driven approach to assessing and enhancing public awareness of indoor air quality (IAQ) and its associated health risks. Through extensive surveys and targeted educational initiatives, it identified several key findings related to public awareness of indoor air quality (IAQ):

- Awareness levels varied notably across demographics. Namely, urban, well-educated parents within the Zagreb pilot exhibited the highest awareness and proactive behaviour, whereas the public survey across five EU countries revealed significantly lower awareness, especially among youth and men.
- Several critical knowledge gaps emerged, including limited understanding of radon and its health risks, inadequate awareness of the impact of household products like cleaners, furniture, and cosmetics on IAQ, and a general lack of knowledge about the



importance of regular ventilation. Many participants also failed to recognise indoor air pollution as a serious health threat.

- Notably, women consistently scored higher than men in IAQ-related knowledge, behaviours, and attitudes.

In response to these findings, the project developed and is disseminating tailored educational materials for children, adolescents, and adults. These and other awareness-raising efforts are being carried out through school workshops, public lectures, social media campaigns, and webinars.

To improve awareness and behaviour regarding indoor air quality (IAQ), the EDIAQI project recommends several strategic actions:

- Future campaigns should prioritise youth and men, who were found to have lower levels of awareness and engagement.
- Educational content should highlight the risks of radon, the harmful effects of certain household products and the importance of proper ventilation and regular household appliances maintenance.
- Schools should be utilised as central hubs for awareness-raising among younger populations, with teachers provided structured guides and interactive materials.
- Community outreach should be expanded through libraries and similar local organisations.

In conclusion, the awareness campaign successfully addressed the EDIAQI long-term objectives through a structured, evidence-based approach that integrated qualitative research, cross-national data collection, stakeholder collaboration, and targeted public engagement activities. Namely, to evaluate public knowledge on pollution-related health effects, the project developed and administered both long and short questionnaires across multiple European countries, revealing critical gaps in understanding and highlighting demographic differences in awareness levels. In defining best practices for raising awareness, EDIAQI used insights from the surveys to design age-appropriate educational materials, including interactive workbooks, videos, and classroom activities, and is disseminating them through schools, libraries, and public workshops. To increase awareness of pollution sources and mitigation strategies, the project addressed specific behaviours



such as ventilation habits, cleaning routines, and product choices, through the creation of targeted educational content and public messaging via webinars, workshops and blogs. Potential disparities in information reach were addressed by identifying underserved groups - such as youth and lower-educated individuals - and adapting materials, accordingly, including translating resources into ten languages and partnering with schools and local institutions (libraries) to ensure inclusive access. Finally, EDIAQI critically assessed public information sources by examining where participants currently receive IAQ information and their perceptions of control, finding that media and informal learning dominated, while institutional sources were underused. In response, the project filled these gaps by providing practical, accessible resources that emphasised both the causes of and solutions to indoor air pollution, ultimately empowering citizens to take informed action in their daily lives. A more detailed report can be found in the D5.5. deliverable ("Report for presenting a novel method for assessing air pollution and building related health risk awareness based on qualitative research").



11 Conclusions

The EDIAQI project's pilot and campaigns demonstrate significant progress in understanding and addressing IAQ across Europe. Through various pilot studies and initiatives, the project has:

- Established data infrastructure and monitoring networks to enable thorough assessments of IAQ.
- Identified the main sources of indoor air pollution in various environments, offering targeted insights for effective mitigation strategies.
- Evaluated the performance of low-cost sensors and filtration systems to guide decisions for effective and practical indoor air quality management.
- Raised awareness and encouraged behavioural changes regarding indoor air quality, empowering citizens to take informed action.

Based on these findings, the main recommendations are:

- Prioritise data quality and interoperability in IAQ monitoring efforts to ensure that the collected data is reliable and comparable.
- Customise interventions to address specific pollution sources and meet building users' needs, thereby enhancing the effectiveness of IAQ improvement strategies.
- Promote comprehensive indoor air quality management approaches that consider ventilation, source control, and air purification to optimise indoor environments for health and well-being.
- Continue to educate and engage the public on IAQ issues, empowering communities to create healthier indoor spaces

By adopting these recommendations, stakeholders can leverage the findings of the EDIAQI project to achieve improvements in IAQ.





Deliverable D4.2

A Compendium of Pilot Reports and Findings

Work Package 4

MONITOR – Pilots, data and campaigns

Version: Final



This project has received funding from the European Union's Horizon Europe Framework Programme under grant agreement N° 101057497.