IDEAL

When Children Breathe: the Impact of Indoor Air Quality on Children's Health Policy Brief

1. Introduction

Air pollution is often associated with outdoor environments. However, air quality does not stop at one's doorstep, and therefore indoor air quality (IAQ) deserves equal concern. Microbes, allergens and chemicals can all compromise IAQ and negatively impact health. People spend most of their time indoors, therefore IAQ in buildings, such as schools and private homes, plays a significant role in health and overall well-being (1).

Indoor air pollutant concentrations are determined by a complex interplay of factors: building-related elements (construction materials, insulation), equipment (heating, cooking, ventilation, and furniture), maintenance practices (HVAC system upkeep), consumer products (cleaning, air freshening, and cosmetic products), occupant-related behaviours (smoking and crowding), and the surrounding ambient environment (1).

In addition, climate change is a key driver of increased temperature and humidity levels, raising the risk of viral, bacterial, and fungal contamination by favouring more thermotolerant species that are more pathogenic to humans (1,2,3). Furthermore, for the large and steadily increasing allergic population, allergens also act as pollutants and in some cases become synergistic with other biological and chemical pollutants (4).

This second IDEAL Cluster Joint Policy Brief resumes the endeavour to explore key aspects of IAQ in Europe, with a thematic focus on children as a particularly vulnerable population group.

2. Background

2.1. Children as a vulnerable group

Children spend 80-90% of their time indoors (5). Throughout infancy and early childhood, most of this time is at home, while as they grow up an increasing amount of time is also spent in daycare and school.

Children are more vulnerable to poor IAQ than adults for a variety of reasons (1,6-9):

- Their respiratory organs and immune system are still developing.
- Because they are growing and often more physically active than adults, children have higher metabolic rates, which means they have a higher air intake relative to body weight.
- Infants and toddlers present increased hand-to-mouth behaviour and thus settled dust contributes to their total body burden.
- The air children breathe is closer to the ground, putting them in closer proximity to sources of some pollutants.
- Children from socioeconomically disadvantaged families often face greater risks because of limited access to healthy housing often residing in areas with higher pollution levels further compounding existing health inequalities.

Therefore, recognising and mitigating IAQ-related risks in environments frequented by children must be treated as an urgent public health priority, demanding coordinated efforts in building design, ventilation standards, policy enforcement, and community awareness.

2.2. Health risks of poor IAQ on children

Poor IAQ has major negative outcomes for children's health, resulting in significant morbidity that often persists into adulthood, and may contribute to mortality. ***Major health effects include impaired lung growth and function, lower respiratory tract infections, the onset and exacerbation of allergy and asthma, as well as respiratory complications in later life*** (10). Pneumonia accounts for 14% of deaths under 5 years of age, while asthma is the most common chronic disease amongst children (11). At the same time, poor IAQ in classrooms can lead to adverse ***educational and mental health outcomes***, negatively impacting student learning performance, attendance, and cognitive development (12,13,14).

Fine particulate matter ($PM_{2,5}$) and volatile organic compounds (VOCs), emitted by construction materials, cleaning products and cooking, have been widely associated with asthma symptoms, respiratory irritation, allergic rhinitis and cognitive impairments (15). Endocrine disruptors (EDs), commonly used as preservatives and biocides, are another example linked with reproductive and developmental disorders, and influencing prenatal/postnatal growth, thyroid function, obesity risk, and fertility. Though EDs are under regulatory restriction, they persist in materials and accumulate in indoor dust (16,17).

2.3. Brief assessment of EU policy framework related to IAQ and children

Clean, healthy air is recognised in local, national, European, and international law as a fundamental human right (18-24). Today, 19 EU Member States have constitutionally enshrined the right to a healthy environment—including air quality (25). However, still today EU IAQ action looks more like a ***patchwork of measures from different policies than a coherent framework***. IAQ is not tackled in a targeted way, but rather as lateral dimension of other EU policies.

The European Green Deal (26) and ***the Zero Pollution Action Plan*** (ZPAP) (27) set the strategic goals of reducing air pollution in the EU. Arising from the ZPAP, the revised ***Ambient Air Quality Directive*** (AAQD) refers explicitly to sensitive populations, including specific provisions related to children e.g. AQ plans to include child-specific health measures; and AQ sampling in areas such as schools and playgrounds. However, while it is key to recognise that better outdoor AQ also benefits indoor settings, the scope of AAQD does not include indoor spaces (23).

From a disease-specific perspective, ***Europe's Beating Cancer Plan*** of 2021 prescribes action across policy silos identifying key risk factors, some of which pertain to indoor environments, including air pollution and tobacco use (28).

Sectoral frameworks

Smoking	***The Council Recommendation on Smoke-Free Environments*** (2009) sets a key precedent for action to address IAQ on health grounds, tackling second-hand smoke exposures. The revised recommendation (2024) also aims to protect children and young people extending coverage to emerging smoking and nicotine-based products (29).
Chemicals	The EU aims to protect health and ensure a toxic-free environment via the ***Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH, EC 1907/2006)*** (30). REACH tackles substances present indoors, such as formaldehyde and phthalates found in children's toys.
Consumer products	The ***Tobacco Products Directive 2014/40/EU*** (31) regulates the presentation and sale of tobacco and related products. It indirectly impacts IAQ, as it ultimately aims to reduce use, and tackle passive smoking. Still exposed in alarming rates to second-hand smoke, most often at home, children may face serious health problems. Furthermore, the ***Detergents Regulation*** (2004) restricts toxic chemicals in cleaning products (32), while the ***Ecodesign Regulation (EU 2024/1781)*** embeds non-toxicity from the design phase, highlighting ventilation systems as a priority product group (33).
Buildings	The ***Energy Performance of Buildings Directive (EU 2024/1275)*** introduces a definition of Indoor Environmental Quality (IEQ) (34). The ***Construction Products Regulation (EU 2024/3110)*** aims to protect against hygiene and health impacts, including harmful VOC emissions (35). In addition, the ***New European Bauhaus*** (2021) addresses health, wellbeing, and sustainability indoors (36). Building on this, the ***EU Affordable Housing Plan***, expected in 2026, presents a unique opportunity to reiterate the importance of in housing, as socioeconomic inequalities go hand-in-hand with the healthiness of living environments.
Digital and research policy	EU legislation provides citizens with the knowledge and tools to take ownership of IAQ. Open access to user-generated data – such as from AQ sensors – as the ***Data Act*** (37) mandates, can empower citizens to respond in real time. Besides, the ***European Strategy for Data*** (38), the ***AI Act*** lays out principles of responsible innovation (39), sensor interoperability, window systems, as well as ventilation and filtration technologies that can galvanise intelligent IAQ management. Furthermore, through its ***Horizon Europe programme*** (40), the EU supports initiatives addressing IAQ, such as the IDEAL Cluster projects.
WHO global guidelines	The ***World Health Organisation Air Quality Guidelines of 2021*** derive evidence-based recommendations for the protection of human health from air pollution (41), applying to both outdoor and indoor settings. WHO also has a track record of work on IAQ-related issues. Three thematic guidelines on ***dampness and mould (2009), selected indoor pollutants (2010), and household fuel combustion (2014)*** (42-44), contain key findings, insights on diseases such as allergy and asthma, and recommendations for better energy use.

3. Findings across projects

Across 20 European countries, the seven IDEAL Cluster projects are addressing the challenges of IAQ (see Figure 1) in children's environments, each project conducting pilots in different countries and settings. Together, they provide broad evidence on IAQ-related challenges.

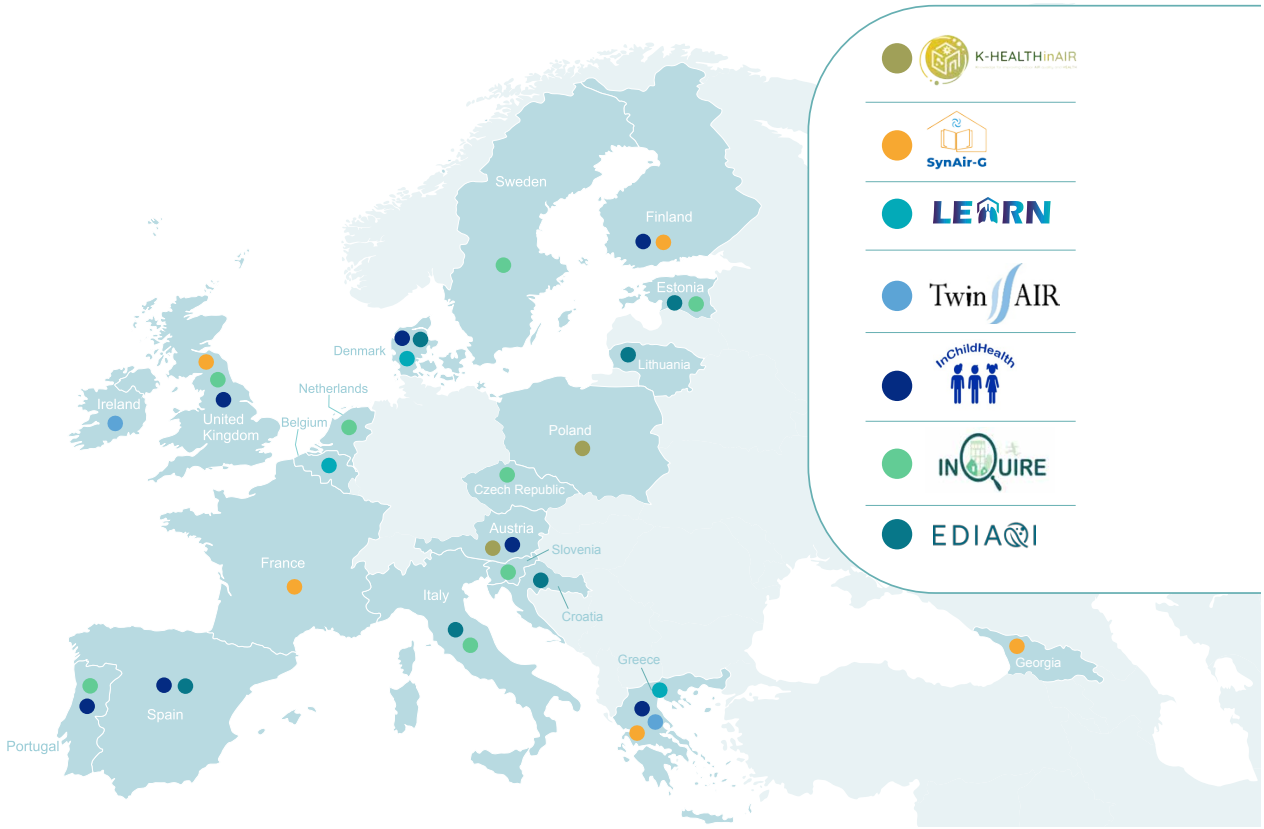

Figure 1 - *IDEAL Cluster pilot sites with a specific focus on IAQ in children's settings (Schools and Homes).*

Settings and population

Settings included homes and schools (kindergartens, primary and secondary schools). IAQ monitoring was conducted in the classroom and teachers' rooms in schools and living rooms of private homes. The studied populations ranged from toddlers aged 2-5 years old to adolescents up to 19 years old. Figure 2 illustrates the overall representation of the settings and population present across the projects. This diversity allows comparison across different age groups and environments.

Project	*Location*	*Setting*	*Age Group*	*Participants*
K-HEALTHinAIR	Austria, Poland	25 Schools	6-19 years	374
INQUIRE	Sweden, UK, Czech Republic, Estonia, Italy, Netherlands, Portugal, Slovenia	205 Homes	2-5 years	205
InChildHealth	Finland, Spain, Denmark, Austria, UK, Portugal, Greece, Australia	45 Schools 37 Homes	6-13 years	4643
LEARN	Belgium, Denmark, Greece	12 Schools	9-12 years	384
TwinAir	Greece, Ireland	8 Schools	6 -12 years	500
SynAir-G	Greece, UK, Finland, France, Georgia	25 Schools	7-10 years	1165
EDIAQI	Italy, Croatia, Estonia, Spain, Lithuania, Denmark	29 Schools 11 Kindergartens 1 day-care centre 189 homes	3 months -18 years	641

Figure 2 - *Overall representation of the different settings and targeted age groups.*

3.1. IAQ measurements

Monitoring across projects generally covered key pollutants such as CO_2, $PM_{2.5}$, ultrafine particle, VOCs, microorganisms, such as bacteria and fungi, as well as natural toxins (endotoxins and mycotoxins). In most cases, monitoring was carried out through the strategic placement of low-cost sensors, enabling continuous measurement. It is important to note that pollutant limits vary across settings and between countries, as there is ***no single European standard regulating all parameters***, while monitoring practices also vary depending on the environment. These differences can limit the direct comparability of projects' results. To address this issue, various projects have collected harmonised contextual, clinical, and environmental data to ensure comparability with other child-focused IAQ studies within the IDEAL Cluster.

Figure 3 and Figure 4 present data from schools monitored in the ***K-HEALTHinAIR*** and ***SynAir-G*** projects, while Figure 5 reports data from homes with children monitored in the ***INQUIRE*** project. Collectively, these findings indicate that both schools and homes—two of the most critical indoor environments for children—face significant and recurring issues with IAQ.

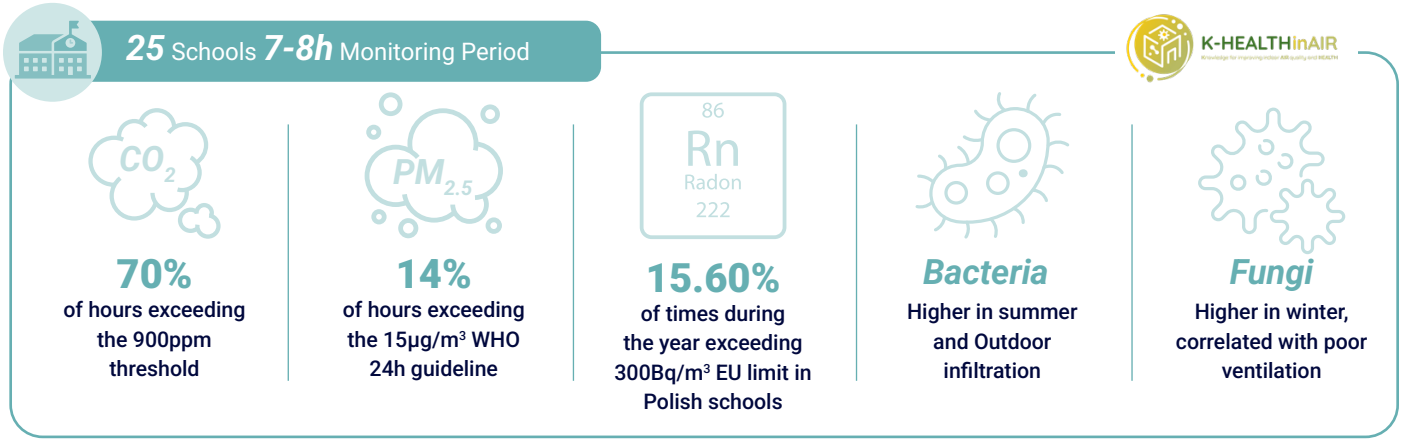

Figure 3 – *Monitoring results from K-HEALTHinAIR pollutants in 25 schools from Austria and Poland.*

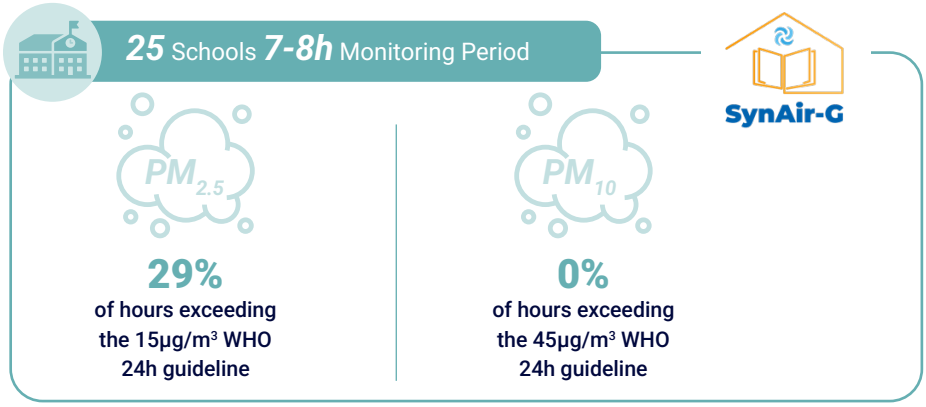

Figure 4 – *Monitoring results from SynAir-G pollutants in 25 schools across 5 European countries: Greece, UK, Finland, France and Georgia.*

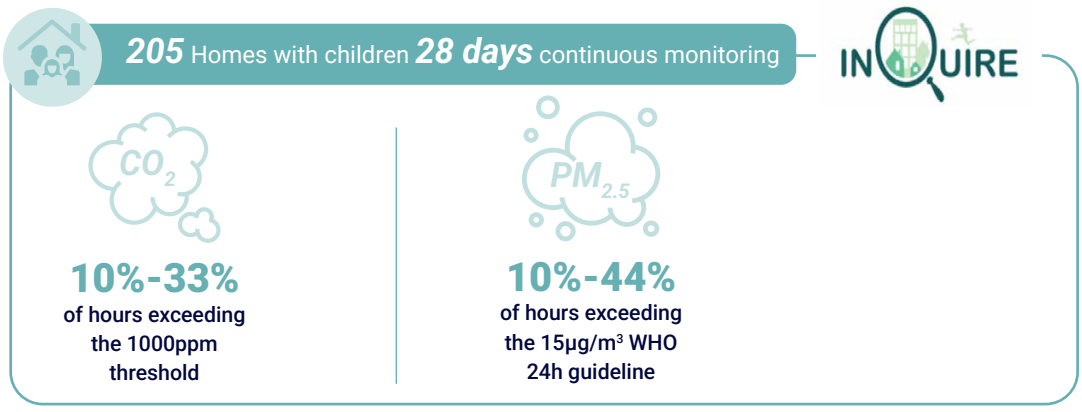

Figure 5 – *Monitoring results from INQUIRE pollutants in 205 homes with children across 8 European countries: Sweden, UK, Czech Republic, Estonia, Italy, Netherlands, Portugal and Slovenia.*

3.2. Prevalence of children's symptoms

Data from ***INQUIRE***'s health questionnaire, which was completed for 205 children, revealed high levels of reported symptoms. Some of the children have already exhibited symptoms such as wheezing (14.5%), throat issues (43.5%), and nasal problems (80.5%), along with health conditions diagnosed by doctors, like allergies (7.9%) and asthma (5.1%).

In the ***EDIAQI*** project, the Zagreb pilot enrolled over 200 children in a longitudinal cohort combining IAQ measurements in homes with lifestyle and symptom questionnaires, generating a dataset to explore links between indoor environments and respiratory risk for children, with results still pending. In parallel, ***EDIAQI*** activities in Denmark draw on health questionnaire data from 182 children (110 severe asthma cases and 72 control) and indoor assessments from 37 households. The analyses showed that asthma symptoms severity is associated with reduced indoor dust microbiome diversity, while PAH levels in house dust did not differ significantly between symptomatic cases and controls.

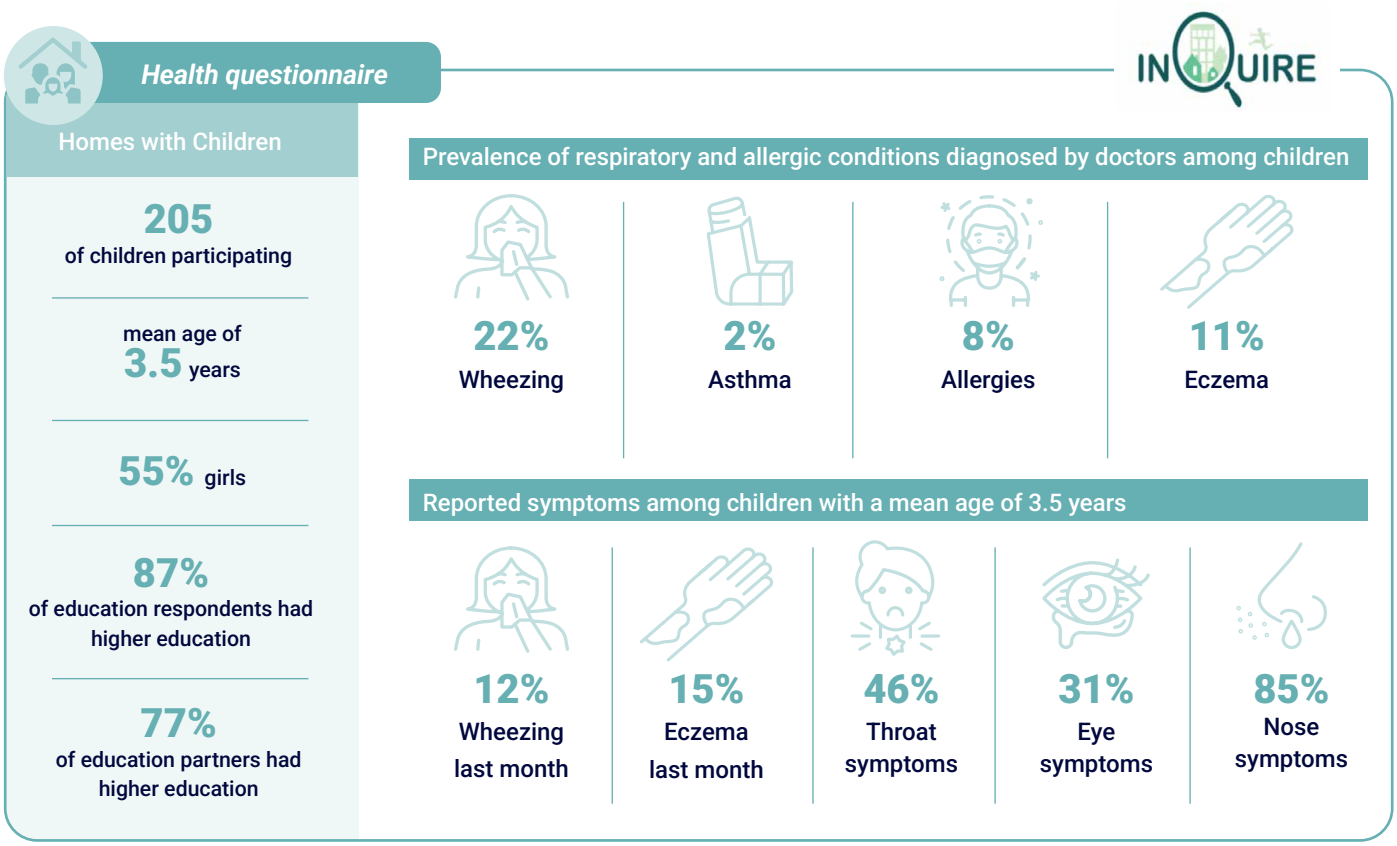

Figure 6 – *INQUIRE Health Questionnaire Results on respiratory and allergic conditions among children across 6 european countries: Czech Republic, Estonia, Italy, Netherlands, Portugal, and Slovenia.*

3.3. Awareness about IAQ

K-HEALTHinAIR conducted a survey with 22 Austrian schoolteachers to assess their knowledge and training needs regarding IAQ. Most teachers (91%) were familiar with IAQ and recognized its importance, yet 68% reported limited knowledge among students and families, as well as gaps in their own understanding. Additionally, 41% noted varying awareness of existing school measures to improve IAQ. Regarding training needs, 82% of teachers highlighted the necessity for practical strategies, especially in ventilation (35%) and pollutant sources (22%), to enhance student knowledge and promote healthier behaviors.

In parallel, ***EDIAQI*** surveyed 706 participants across five European countries (Italy, Croatia, Spain, Lithuania, and Estonia). Most respondents were from Italy and Croatia and consisted primarily of adults and parents from household settings. Results showed that 65% had little or no knowledge of indoor air pollution, over 50% did not ventilate regularly during the winter, and around 30% were unwilling to pay more for cleaner indoor environments, underscoring awareness and behavioural gaps.

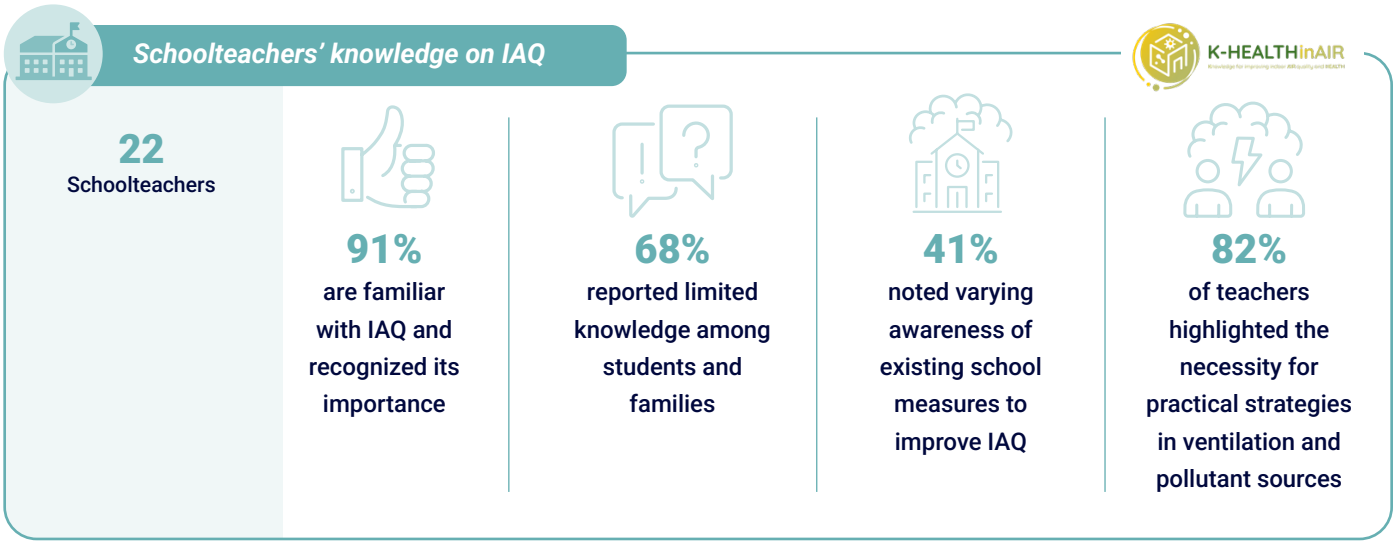

Figure 7 – *Assessment of IAQ awareness and training requirements among Austrian schoolteachers within K-HEALTHinAIR project*

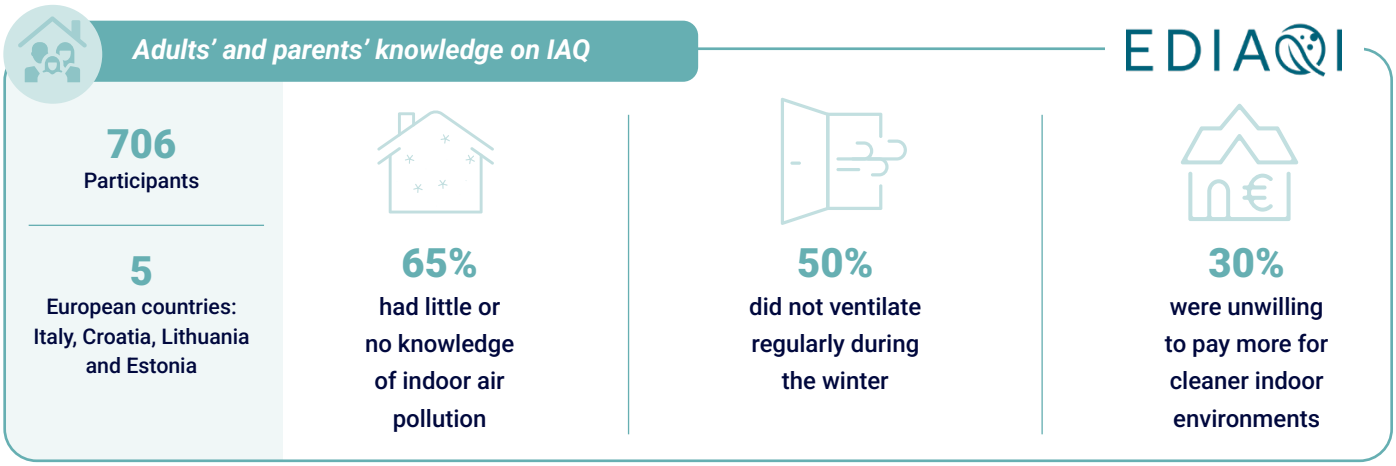

Figure 8 – *Assessment of IAQ knowledge and behaviour among adults and parents within EDIAQI project*

3.4.Solutions to improve awareness and IAQ

Technical solutions on improving IAQ

Occupancy rates and ventilation conditions strongly influence pollutant levels. For microbiological contaminants and CO_2, effective ventilation practices can help reduce concentrations. ***K-HEALTHinAIR*** identified seasonal variations in fungal contamination in school indoor air. For example, opening windows improves ventilation and reduces bacterial contamination but may increase fungal contamination during summer. Therefore, filters with high air exchange rates appear to be more effective in reducing microbiological contamination in classrooms. ***InChildHealth*** found that cleaning practices substantially affect microbial contamination, underscoring the need for clear guidance on cleaning protocols in their dedicated Policy Brief[1].

Similarly, an ***INQUIRE*** study found that air filtration was effective in reducing indoor $PM_{2.5}$ concentrations by 60-90% per home; and ***LEARN*** reported that air filtration capable of removing both particles and gases improved children's cognitive function. However, outdoor air quality, local climate, heating and cooling demand, and filter type, should be considered when deploying air filtration. For example, air filtration is well-suited to spaces with poor outdoor air quality, where opening windows will not improve IAQ. Conversely, in areas with good outdoor air quality, natural ventilation may suffice and can save energy and reduce CO_2 emissions.

SynAir-G developed and installed "green walls" in 8 schools—vertical structures covered with vegetation that serve a dual purpose: they filter and purify indoor air, while also enhancing the aesthetic quality of the environment. Green walls have been proven to reduce and eliminate symptoms like redness and irritation of eyes, cold, itchy nose and sneezing, sore and irritated throat, dry skin and rash, by purifying and humidifying indoor air.

Solutions to drive awareness and increase knowledge

In ***EDIAQI,*** the development of the integrated child-friendly Air Quality Beacon and Emission Evaluator[2] enabled high-resolution monitoring of pollutants and allergens in schools and homes. Via complementary educational tools and training materials for children,[3] EDIAQI promoted improved ventilation, filtration, and maintenance practices, advancing both the technological and behavioural dimensions of IAQ management

As part of its activities, ***InChildHealth*** created an Indoor Air Quality Kit for pupils[4]. On Children's Day, more than 16,000 students across Lisbon received the kit, which enabled hands-on exploration of air quality and environmental science. This activity marked a significant step in promoting scientific literacy, engaging the local community, and inspiring the next generation to take an active role in improving indoor environments.

K-HEALTHinAIR emphasizes capacity-building through knowledge dissemination and stakeholder engagement. All educational materials, including newsletters, policy briefs, personalized infographics, and webinars, are available on the Open Access Platform.[5] These resources connect scientific evidence with practical application in schools and support awareness-raising efforts about IAQ.

LEARN has produced *Clean air in school! Play & LEARN*, a board game that gives children a fun and collaborative way to learn about indoor air quality and how to improve it. Available[6] for free in multiple languages, the game is aimed at children aged 9-12 and can be used as a classroom resource by teachers.

TwinAir approaches the school environments by integrating different components in a single system: hardware installations (sensors and filtration systems) and a digital toolkit which includes building digital twin and social engagement tools.

The findings from these projects demonstrate that there is no single solution for improving IAQ. Instead, success depends on combining multiple strategies—ranging from simple practices like proper ventilation and the use of educational tools, to more advanced interventions such as high-efficiency filtration systems, as illustrated in Figure 9.

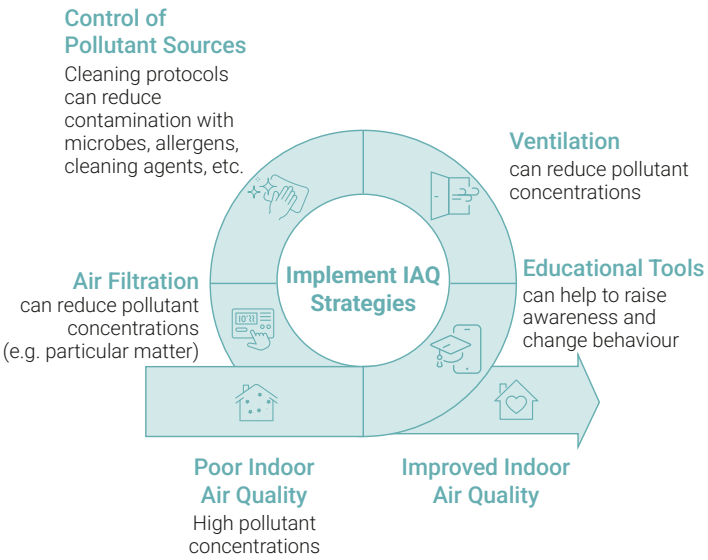

Figure 9 – *Solutions to improve awareness and IAQ.*

1 Available at: https://inchildhealth.eu/policy-brief/
2 Available at: https://ediaqi.eu/articles/air-quality-beacon-and-immission-evaluator-turning-indoor-air-data-action
3 Available at: https://ediaqi.eu/resources/training-materials
4 Available at: https://inchildhealth.eu/inchildhealth-indoor-air-explorer-kit/
5 Available at: https://k-healthinair.eu/knowledge/sharing/
6 Available at: https://www.learnproject-heu.eu/learn-project-board-game-free-download/

4. Conclusion

While outdoor air pollution captures public attention, children face an invisible threat indoors, where they spend up to 90% of their time. Poor IAQ in schools and homes causes preventable harm to children's respiratory health and cognitive development. ***There is a clear gap between science and policy*** that demands urgent attention.

The evidence from across the IDEAL Cluster projects highlight a persistent challenge: ***IAQ in schools and homes remains a critical yet under-addressed factor affecting children's health, wellbeing, and learning potential***. Pollutant levels, especially CO_2, $PM_{2,5}$, and microorganisms, often exceed recommended thresholds, reflecting the combined effects of insufficient ventilation, high occupancy, and limited filtration. These findings emphasise that the environments where children spend most of their time are not consistently healthy or safe.

Despite the lack of a ***coherent, binding EU framework***, the results from these projects also demonstrate that ***clean indoor air for children is within reach***. Every child has the right to live and learn in a healthy environment. Protecting children's IAQ is both an attainable goal and a moral imperative—an investment in the wellbeing, potential, and future of the next generation.

By translating scientific evidence into policy, coordinated EU action can bridge existing gaps and create healthier, fairer learning environments across Europe. Establishing standardised IAQ monitoring and reporting across Member States is a vital first step towards effective regulation.

5. Recommendations for EU-level action

The evidence is clear: children across Europe are systematically exposed to harmful IAQ levels in the places where they learn and live. Current policy frameworks are fragmented and fail to establish enforceable standards. This is not inevitable. Effective solutions exist—from improved ventilation and filtration systems to smart monitoring technologies. The IDEAL Cluster projects demonstrate that protecting children's IAQ is both technically feasible and cost-effective.

The question facing EU institutions should no longer be whether IAQ poses a threat on children and public health, but how quickly comprehensive action can be taken. We highly recommend EU policymakers to take leadership in tackling IAQ by:

1. Proposing a coherent and dedicated ***IAQ framework***, in the form of roadmap/action plan, especially for those populations most at risk such as children and young people;
2. Integrating ***IAQ targets and considerations in the context of related sectoral policies*** that affect children, including on renovation/construction of buildings, housing, research, the evolution of AI, as well as the revisions of the chemicals and detergents regulations;
3. Initiating efforts for the adoption of a ***minimum EU health-based IAQ standard*** for all new school buildings, as well as the integration of appropriate technological solutions, such as filtration;
4. Leading the work to ***increase knowledge***, supporting EU-wide and national awareness campaigns targeting policymakers, teachers, administrators, families and the public on the impact of poor IAQ on children's health; and how schools can mitigate its effects;
5. Facilitating the adoption of ***emerging technological solutions*** to ensure better monitoring, effective management and improved overall IAQ, with a focus on school environments;
6. Fostering the ***exchange of best practices*** among Member States in the scope of IAQ and school educational settings.

→ References → ANNEX – IAQ best practices