



Development of novel assessments for indoor air quality monitoring and impact on children's health

Proof of inactivation or no harm of collected contaminants in filter media

LEARN

MANN+HUMMEL GMBH



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Project details

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The LEARN Consortium

Participants n°	Participant Organisation Name	Country
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2	Vrije Universiteit Brussel (VUB)	BE
3	Envirometrics Technikoï Symvouloi Etaireia Periorismenis Efthynis (ENV)	EL
4	Katholieke Universiteit Leuven (KUL)	BE
5	Universiteit Hasselt (UH)	BE
6	Mann+Hummel GMBH (M&H)	DE
7	Nanotechnology Industries Association (NIA)	BE
8	Stichting IMEC Nederland (IMEC-NL)	NL
9	Aarhus Universitet (AU)	DK
10	F. Iniciativas España Mas i Mas SLU (FI)	ES
11	AlveoliX (AL)	CH
12	Technische Universiteit Eindhoven (TU/e)	NL

Project's aim

LEARNing about the status of air quality in schools and its impact on the cognition of children is a major cornerstone in LEARN. For that, we want to overcome the barriers of the currently existing technologies and take a bold step towards developing and deploying novel sensors to detect the presence of possibly harmful air pollutants such as volatile organic compounds and ultrafine particles.

We will measure and characterize indoor and outdoor air pollutants and evaluate the presence of biomarkers of exposure and their effect on children's cognition while trying to recapitulate those effects using *C.elegans* as a biosensor. Moreover, we will use advanced human-based in vitro models of lung and skin coupled with a revolutionary multi-sensing device to investigate their mechanisms of toxicity in real-time.

Novel remediation strategies will be explored to improve air quality and promote children's quality of life and life expectancy. For that, we will mobilize a group of eleven leading research teams, unrivalled in their respective fields (environmental epidemiologists, toxicologists, air quality specialists, systems biology, engineers, and citizen/social scientists).

The scientific achievements expected to result from LEARN will unlock a large technology potential in IAQ for decades to come, leading to disruptive societal and economic impacts stemming from a radical improvement in the quality of life of children in Europe.

Project LEARN is part of the European indoor air quality and health cluster.

Document details

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The following table describes the main changes done in the document since it was created

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V.1.0	June 22, 2026	Version for partner's release	M&H

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1. Executive summary

Deliverable D6.4 addresses the question whether contaminants collected in air purifier filter media used in indoor environments such as classrooms may pose hygienic and/or health-related risks, and whether additional protective measures such as antimicrobial or antiviral functionalization of the filter media should be considered.

The original plan was to analyze used filter elements returned from the LEARN school cohort studies in Belgium and Denmark. However, because the exposure time of these filters to classroom air was only a few weeks, the returned samples did not contain sufficient contamination mass for a meaningful analytical assessment. In order to still investigate the topic and derive generally relevant conclusions for indoor air use cases, the sample strategy was adapted: similar filter elements from a different but comparable application, namely air purifiers operated for multiple months in an office building and a canteen, were selected as substitute samples expected to provide higher contaminant loading.

These long-term exposed filters were sent to project partner Laboratorio Iberico Internacional de Nanotecnología (INL) for analysis. However, the filters reached INL only in April 2026. Due to the decision not to extend the project duration, the analytical work could no longer be completed within the project period and therefore no experimental results can be presented by the due date of this deliverable.

This report therefore documents the original objective, the adapted investigation strategy, the reasons why the planned analysis could not be finalized in time, and the planned next steps after project closure. If the subsequent analyses indicate that collected contaminants could represent a relevant hygienic or health concern, mitigation solutions are available. These include antimicrobial and/or antiviral functionalities already used on other air filtration products, including applications with direct human exposure relevance such as automotive cabin air filters. One example is MANN+HUMMEL's PreciousPlus technology, a biocide-free coating approach.

2. Introduction and objective of D6.4

2.1. Context

Within Work Package 6, the LEARN project investigated remediation strategies to improve indoor air quality in school environments. Besides particle and gas removal performance, a relevant safety-related question is whether contaminants captured and accumulated in filter media can themselves become a hygienic or health-related concern during use. This question is

particularly important in classrooms, where children represent a potentially more vulnerable user group.

The consideration includes, in particular:

- whether relevant microbial contamination accumulates in the filter media,
- whether collected biological or chemical contaminants could create a secondary exposure risk,
- whether the use of additional protective media functionalities such as antimicrobial or antiviral coatings would be justified.

2.2. Objectives of Deliverable D6.4

The original objective of D6.4 was to provide an evidence-based assessment of whether contaminants collected by the LEARN air purifier filters are either inactivated, harmless under the investigated use conditions, or potentially relevant from a hygiene and health perspective.

More specifically, D6.4 was intended to:

- assess used filter media from LEARN cohort studies for relevant contamination,
- identify whether microbial or other collected contaminants indicate potential hygienic or health risks,
- evaluate whether further protective measures on the filter media could be beneficial,
- support the decision whether antimicrobial and/or antiviral treatment concepts should be considered for indoor air purifier filters in school environments.

3. Planned approach and deviation from the original analysis concept

3.1. Initial analysis concept based on LEARN cohort filters

The initial analysis strategy was based on collecting and examining used air purifier filter elements from the LEARN cohort studies (WP2), in particular from deployments in Belgium and Denmark. The rationale was that these filters represent the most direct and project-relevant exposure scenario, namely the use of air purifiers in occupied school environments.

The intended workflow was:

1. collect used filter elements after classroom deployment,
2. transfer representative filter samples to project partner INL,

3. analyze the retained contamination load with focus on relevant microbial and other potentially critical contaminants,
4. interpret the results regarding possible hygienic and health implications for indoor use,
5. derive recommendations regarding the need, or absence of need, for additional antimicrobial or antiviral functionalities.

3.2. Limitation of returned classroom filter samples

Used filter elements were returned from the LEARN WP2 cohort studies in Belgium and Denmark. However, the practical exposure time of these classroom filters to indoor air was only a few weeks. As a consequence, the total mass of retained contamination on the filters was too low to support a robust and meaningful analytical assessment.

This limitation is plausible in view of the LEARN use case:

- the classroom intervention periods were relatively short,
- indoor particulate concentrations in the investigated schools were not exceptionally high,
- the collected mass available on the filters was therefore insufficient for more conclusive microbiological and/or chemical examination.

As a result, the originally planned sample basis from the school cohorts did not allow a sufficiently reliable proof-of-no-harm or proof-of-relevance analysis.

3.3. Alternative sample strategy using long-term indoor air purifier filters

To still address the scientific question in a meaningful way, the sample strategy was adapted. Instead of relying only on the short-term exposed classroom filters, similar filter elements from another indoor air use case at M&H were selected. These substitute samples came from air purifiers operated for multiple months in an office building and in a canteen.

The rationale for this adaptation was as follows:

- the filter type and basic application principle are comparable to the LEARN remediation context,
- the substantially longer operating period was expected to yield significantly higher contaminant loading,
- the resulting samples were considered better suited for analytical investigation of possible hygienic or health-related relevance of accumulated contaminants,
- the results were expected to allow at least a general interpretation for indoor air purifier applications.
- This alternative approach was intended as a pragmatic mitigation measure to derive technically useful conclusions despite the insufficient loading of the original classroom samples.

4. Status at deliverable due date and interpretation

The long-term exposed indoor air purifier filters intended for the adapted analysis were transferred to INL only beginning of 2026. Because the requested project extension was not granted, there was no remaining project time available for INL to perform the planned analysis before the official end of the project.

Consequently, no analytical results can be reported within D6.4 by the contractual due date. In particular, this means that the deliverable cannot provide:

- a laboratory-based confirmation of inactivation of collected biological contaminants,
- a laboratory-based confirmation of absence of harmful contamination under the investigated conditions,
- a final evidence-based recommendation derived from the intended filter sample analysis.

Nevertheless, several conclusions can still be stated regarding the project outcome and interpretation:

First, the fact that the classroom filters from Belgium and Denmark did not accumulate enough contamination mass within a few weeks to enable a more extensive analysis is itself an indication that, under the specific LEARN cohort exposure conditions and durations, no unusually high loading occurred.

Second, the inability to conclude experimentally within the project period does not indicate the presence of a hygiene problem; rather, it reflects a combination of low sample loading and lack of remaining time for analysis after receipt of the substitute filters.

Third, if future analyses of the long-term exposed indoor filters were to indicate a relevant microbial or hygienic concern, technical mitigation options are available. M&H has experience with functional filter media solutions for direct human-near applications, including automotive cabin air filters. These include technologies designed to support hygienic handling and reduction of biological activity on filter surfaces.

One example is M&H's FreciousPlus technology. FreciousPlus is a biocide-free coating concept that has been successfully applied in other filter product areas and is designed with health and allergy compatibility in mind. In principle, comparable technology approaches could also be transferred to portable air purifier filters or stationary heating, ventilation, and air conditioning (HVAC) filter systems if a specific use case and risk assessment justified such an additional protection layer.

At the same time, the need for such coatings should not be assumed by default. Their application should be based on evidence from the intended use case, taking into account contaminant type, accumulation level, user exposure scenario, service intervals, and product safety requirements.

5. Conclusions and next steps

Deliverable D6.4 was intended to assess whether contaminants collected in LEARN air purifier filter media may represent a hygienic and/or health-related concern and whether additional protective measures such as antimicrobial or antiviral filter treatments should be considered.

The original investigation approach, based on used filters from the LEARN classroom cohorts in Belgium and Denmark, could not yield a robust analytical basis because the practical exposure time was too short and the returned filters contained insufficient contamination mass. To address this limitation, the sample concept was adapted to use similar long-term exposed indoor air purifier filters from an office building and a canteen. However, these substitute samples reached project partner INL only in April 2026, and due to the decision not to extend the project duration, the planned analyses could not be completed within the LEARN project period.

Therefore, D6.4 documents the status, rationale, and limitation of the work rather than final analytical proof. The absence of reportable results by the due date should be understood as a project timing constraint combined with insufficient sample loading in the original cohort filters, not as evidence of identified harm.

The planned next steps are:

- to perform the intended analyses after project closure, if feasible between the involved partners,
- to document the outcome in an appropriate follow-up format such as a technical note, internal report, or publication,
- to use the resulting evidence to decide whether additional hygienic protection layers on indoor air filter media are justified for comparable use cases.

If future findings indicate a relevant need, technically mature mitigation options are available, including biocide-free functional coating technologies such as FrecciousPlus that could be evaluated for transfer to air purifier or stationary HVAC filters.

References

MANN+HUMMEL product and technology information on FrecciousPlus coating technology.

<https://www.mann-hummel.com/en/filtration-company/news-press/2021/mann-filter-frecciousplus-provides-clean-air-in-the-vehicle-cabin.html>

ISO 16890 series: Air filters for general ventilation.

EN 1822 / ISO 29463: High efficiency air filters and filter media for removing particles in air.

ISO 846: Plastics — Evaluation of the action of microorganisms.