Observatoire de la qualité de l'air intérieur

OQAI NEWSLETTER n°11 JUNE 2018

Air quality and comfort in French schools: first results of the national campaign

The OQAI (French Indoor Air Quality Observatory) presented the first results of the national campaign on air quality and comfort in 301 nursery and elementary schools in France, at a public workshop on June 25, 2018.

After the home, school is the living space where children spend the most time. In classrooms, indoor air quality depends on numerous factors: the occupancy rate (often high), the density of the furnishings, the cleaning habits and the use of products for activities, such as glue, ink, paint, etc.

About 6 million children attend nursery and elementary schools in France.[1] Good indoor air quality is crucial for these young children, who are more sensitive to air pollution due to their developing immune and respiratory systems. Schools also need to have quiet, well-lit environments designed to foster children's learning. A high-quality indoor environment has positive effects on the school performance of children and on reducing absenteeism rates.

CONTENTS

[1] French Ministry of National Education. Benchmarks and statistical references 2017.

No study had yet provided a statistically representative, overall view of the indoor environment of schools in France, focusing on a large number of pollutants and comfort parameters. The available studies were limited, either to a few indicators, particularly indoor air stuffiness[2] or pollutants (formaldehyde, benzene) in connection with the regulatory monitoring of the indoor air of these premises, or to a few schools studied on the initiative of the local authorities.
Within this context, the OQAI initiated a national campaign in 2013 to measure a large number of indoor air quality and comfort parameters in a representative sample of nursery and elementary schools in France. Its objective was to give a clear picture of the pollution in classroom air and dust and to describe the conditions of comfort.

301 schools surveyed

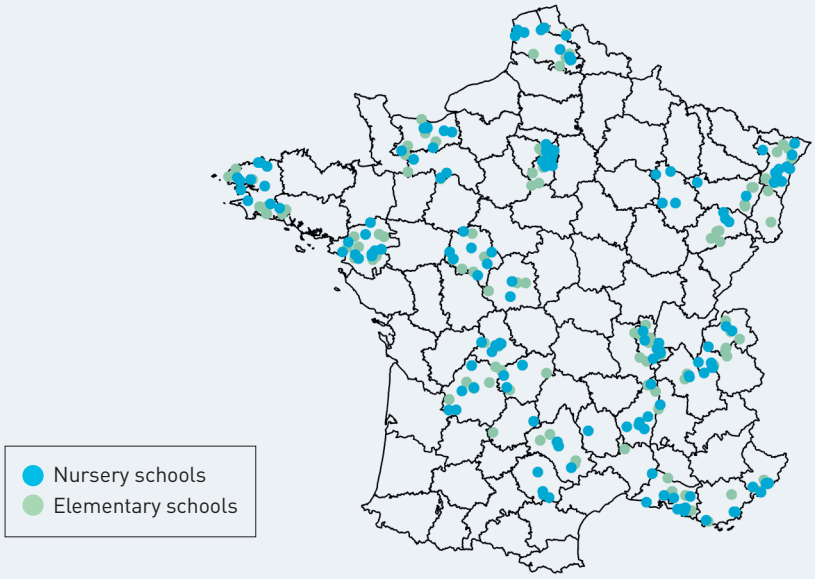
The schools were randomly selected across continental France, to form a representative national sample of schools. There were 52,582 schools at the start of the school year in 2009, according to the latest census issued by the French Ministry of National Education. The sampling was stratified by factors that might influence indoor air quality: the climate zone (as defined in the thermal regulation), the environment (rural or urban) and the type of school (nursery or elementary school).
From June 2013 to June 2017, **301 nursery and elementary** schools in 31 different French counties were surveyed *(Figure 1)*.
12 teams of operators conducted the field surveys and 6 laboratories analyzed the samples.

SOURCES	EXAMPLES OF ASSOCIATED POLLUTANTS
Building occupancy Human and animal presence Daily activities: school supplies and arts-and-crafts supplies (pens, markers, glue, paint, ink, etc.), cleaning products	• Bio-effluents (CO_2, VOCs) • VOCs: alcohols, aldehydes, ketones, hydrocarbons and terpenes • SVOCs: phthalates, musks, pesticides • Particulate matter
Buildings Construction and decoration products: floor and wall coverings, insulation materials, paint, varnish, adhesives and sealants, joints, agglomerated wood, carpets, new fabrics, etc. Water damage, presence of thermal bridges	• VOCs: aldehydes, ketones and hydrocarbons • SVOCs: phthalates, flame retardants (PBDEs), polychlorobiphenyls (PCBs) • Lead • Mold (development on materials)
Office furniture and equipment Furniture IT equipment, photocopiers, chalkboards and whiteboards	• VOCs: aldehydes, alcohols, ketones, terpenes and hydrocarbons • SVOCs: flame retardants (PBDEs), phthalates • Particulate matter • Ozone
Outdoor environment Ground and outdoor air	• Nitrogen dioxide • VOCs: hydrocarbons • SVOCs: polycyclic aromatic hydrocarbons (PAHs), pesticides • Particulate matter • Heavy metals • Radon • Mold (spores)

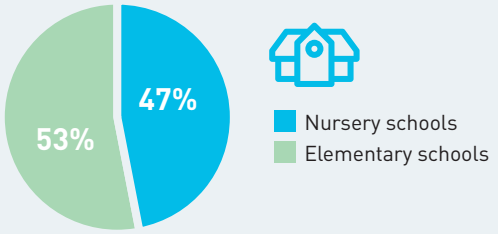
VOCs: volatile organic compounds; SVOCs: semi-volatile organic compounds

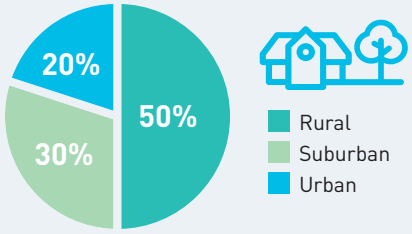
[2] The indoor air stuffiness of a classroom depends on the air renewal in the room and its occupancy rate. It is evaluated by measuring the concentration of carbon dioxide (CO_2).

Figure 1. The 301 schools surveyed between 2013 and 2017

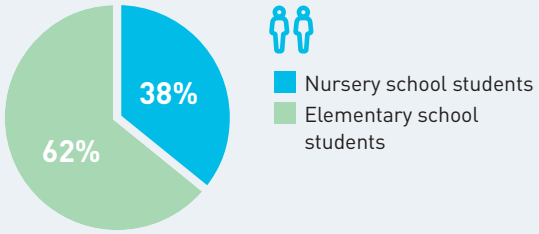


Figures 2 & 3. The schools and their environment





Figures 4 & 5. The students and their environment



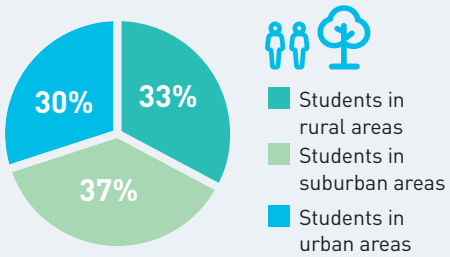


Figure 6. Intensity of traffic around schools, within a 500 meter radius

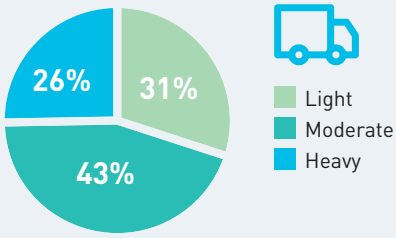
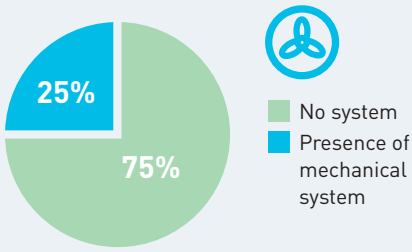


Figure 7. Ventilation system



The campaign

At a glance

- Measuring instruments were installed in **two randomly selected classrooms** per school, for one week, from Monday to Friday.
- **Both air and settled dust** were sampled to measure the substances emitted, particularly by the furniture, coverings/coatings, activity products, cleaning products, or originating from the outdoor environment.

Air pollution

- **64 target pollutants in the air:**
  - 13 volatile organic compounds (VOCs)
  - 3 aldehydes
  - 46 semi-volatile organic compounds (SVOCs)
  - nitrogen dioxide (NO_2)
  - particulate matter with size fraction under 2.5 µm ($PM_{2.5}$)

Contamination of dust on the floor

- **53 target pollutants in the settled dust on the floor**
  - 7 metals including lead
  - 46 semi-volatile organic compounds (SVOCs)

Lead content in paint

Comfort and indoor environment conditions

- **Air temperature, relative humidity and carbon dioxide concentration** (CO_2) recorded continuously in the classrooms during the school week.
- **Noise, lighting and electromagnetic fields.** *The results linked to these data will be processed later.*

Questionnaires were filled in by the field technicians, the managers of the buildings and the teachers, in order to describe the **buildings**, the **classroom activities** and the **occupants' perceived comfort**.

Measurement of VOCs, NO_2, SVOCs, particles, CO_2, temperature, humidity and noise.

What is the air quality in schools?

VOCs and aldehydes always detected

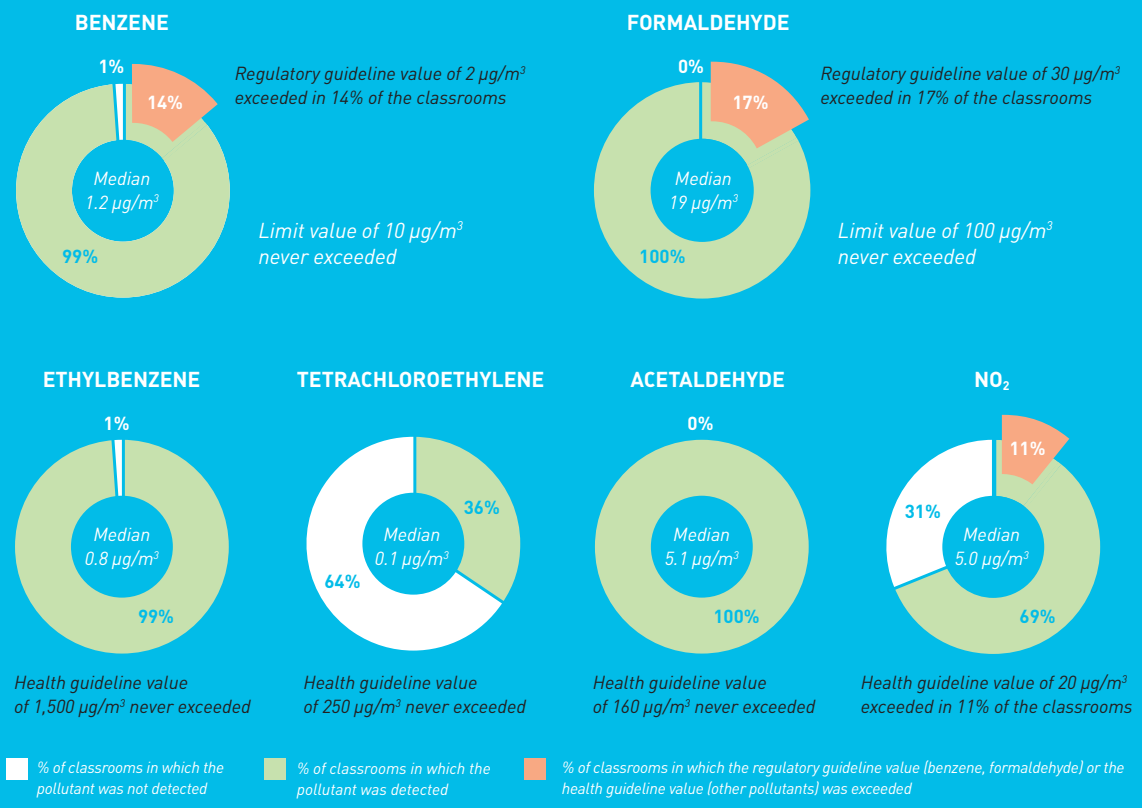
VOCs and aldehydes are emitted by numerous sources in classrooms: furniture, coverings/coatings, cleaning products, activity products, etc. Amongst these compounds, **13 were detected in at least 80% of the schools:** acetaldehyde, alpha-pinene, benzene, decane, ethylbenzene, formaldehyde, hexaldehyde, limonene, m/p-xylenes, methyl isobutyl ketone (MIBK), o-xylene, styrene and toluene. Phenol was detected in half of the air samples, tetrachloroethylene in a third and n-hexane in less than one out of every five schools.

These findings are **relatively similar** to those observed in European schools since 2003.

Low nitrogen dioxide (NO_2) pollution

NO_2 is emitted by combustion sources, such as heaters and gas cookers, which are rarely found in classrooms. In the surveyed schools, NO_2 mainly comes from outdoor sources such as road traffic or industrial sources. Thus, **in a little less than one third of the classrooms, nitrogen dioxide was not detected**. Its median concentration[3] was 5.0 µg/m³.

Figure 8. Detection frequency and percentage by which the reference values were exceeded



*The **regulatory guideline values of indoor air quality** are concentrations in indoor air set with the aim of avoiding, preventing or reducing harmful effects on human health, to be reached whenever possible (Decree 2011-1727 of 2 December 2011 on guideline values for indoor air regarding formaldehyde and benzene). The **health indoor air quality guideline values for indoor air** set by the French Agency for Food, Environmental and Occupational Health & Safety (ANSES) are defined as concentrations in the air below which no health effect or no harm with an impact on health is expected for the general population based on current knowledge. The **limit values** are values that, if exceeded, must be reported to the local authorities and request further investigations.*

[3] The median is the value that splits the sample in half: 50% of the concentrations are below this value and 50% are above it. It is preferred over the mean because it depends less on the maximum values.

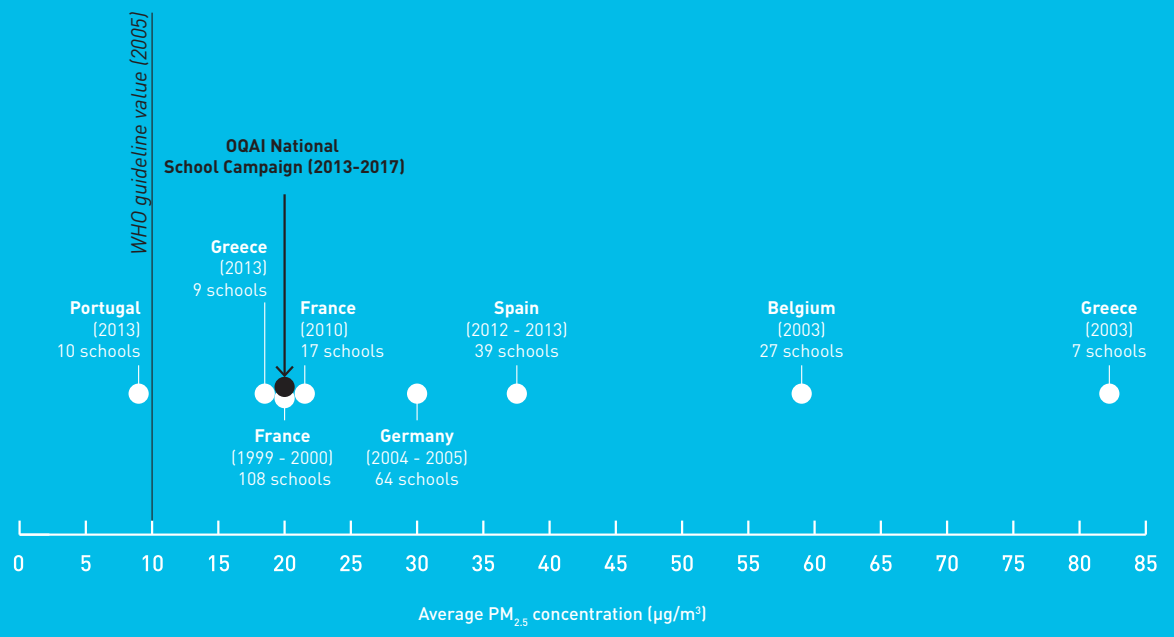
Ubiquitous particle pollution

Particulate matter with a size fraction under 2.5 µm ($PM_{2.5}$), i.e. fine particles, are emitted by combustion. In classrooms, in the absence of combustion sources such as smoking, cooking or incense burning. $PM_{2.5}$ comes mainly from outdoor sources such as road traffic or industrial emissions. **$PM_{2.5}$ was found in the air of all the classrooms;** the median concentration was 18 µg/m³.

These results are comparable to those previously observed during the pilot study in 17 schools of the area of Clermont-Ferrand and during the ISAAC study (*International Study of Asthma and Allergies in Childhood*) in 108 schools in six French cities. The comparison with the European studies shows a wide variability in concentrations *(Figure 9)*, which can be explained in part by the heterogeneity of the sampling techniques used, especially in terms of sampling time and air volume sampled.

Figure 9. Fine particles: comparison between European studies
Average $PM_{2.5}$ concentrations in schools in France and in Europe since 2000

The guideline value of 10 µg/m³ provided by the World Health Organization (WHO) in 2005 for $PM_{2.5}$ and recommended by the French Agency for Food, Environmental and Occupational Health & Safety (ANSES) in 2010 was exceeded in 93% of the classrooms.



Semi-volatile organic compounds (SVOCs): varying concentrations according to the substances

SVOCs are chemical substances contained in materials and consumer products. They come from plastics (phthalates), computers and fabric upholstery (polybrominated flame retardants, PBDEs), cleaning products and cosmetics (synthetic musks: galaxolide and tonalide), insecticides (pyrethroids). Polycyclic aromatic hydrocarbons (PAHs), from combustion processes, and polychlorinated biphenyls (PCBs), banned from use but still present in the sealants of windows and floor coverings from the 1970s, are also considered.

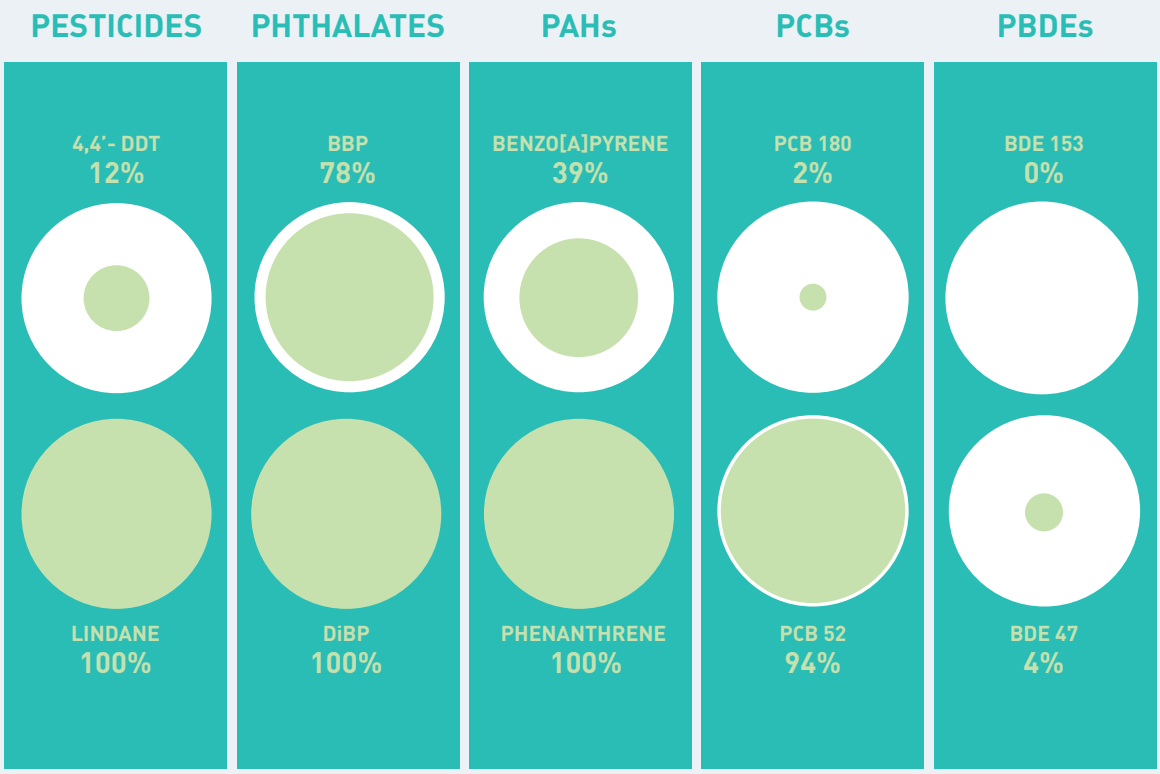
SVOCs were detected in the air of almost all of the schools: 3 phthalates (DiBP, DEP, DBP), 2 musks (tonalide and galaxolide),1 pesticide (lindane), PCB 52 and 4 PAHs (phenanthrene, fluoranthene, acenaphthene, fluorene). In half of the classrooms, at least 20 SVOCs were detected in the air.

Other compounds, such as PBDEs, were rarely, or almost never, detected.

The concentrations were highly variable depending on the compounds: they varied from one hundred ng/m^3 for phthalates to a few pg/m^3 for some pesticides, PCBs and PBDEs.

Worldwide, about 15 studies have been conducted since 2010 in childcare institutions (from daycare centers to middle schools) in 8 countries (Germany, Italy, Norway, Portugal, Lithuania, Serbia, United States and China). Comparing those results with the results from the surveyed schools shows **concentrations similar** to those observed in the French schools for the common target compounds: PAHs, phthalates and tributyl phosphate.

Figure 10. Semi-volatile organic compounds (SVOCs)
Detection frequency in classroom air for a few SVOCs



SCHOOLS LESS POLLUTED THAN HOMES?

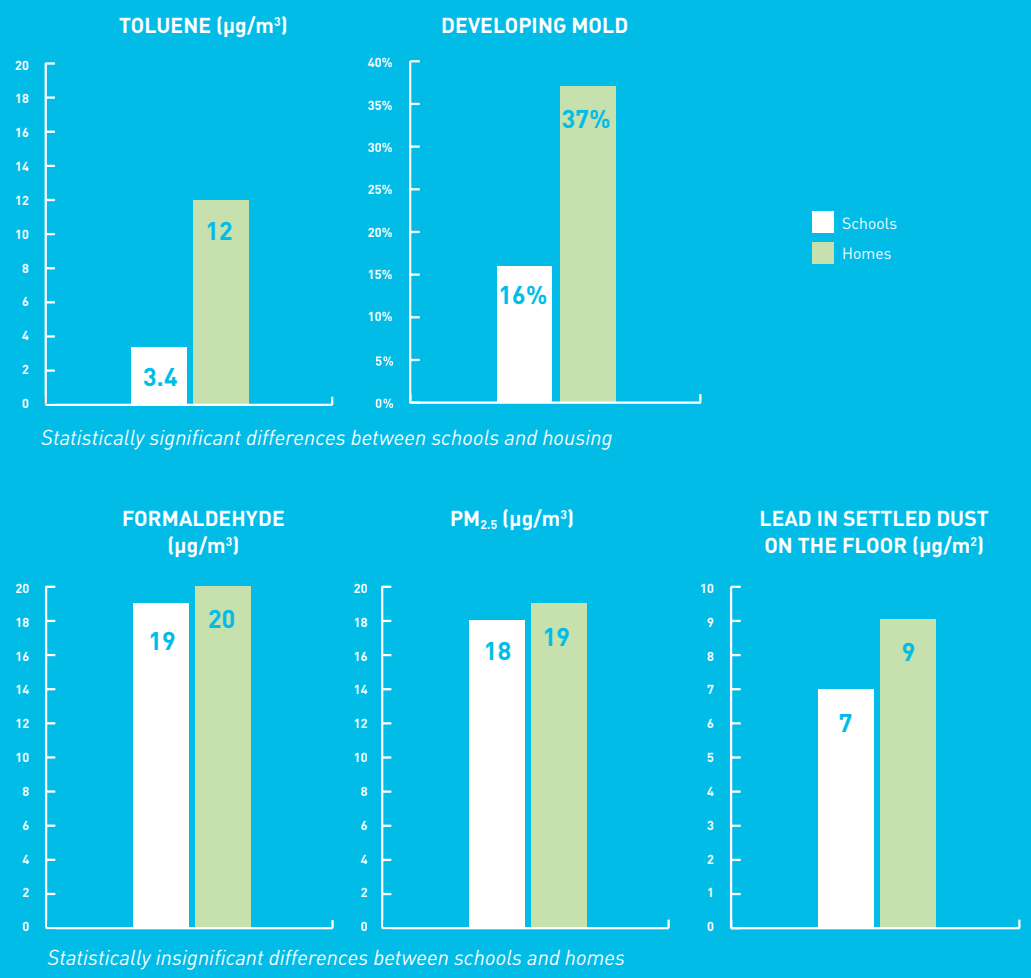
Schools are the places where children spend the most time, other than their homes. Therefore, it is useful to compare the two environments. The comparison was made with data from the National Housing Campaign conducted by the OQAI between 2003 and 2005, with the exception of lead in dust, for which the results of the "Plomb Habitat" campaign (2008-2009) were used for the comparison *(Figure 11)*.

The VOC and aldehyde concentrations were significantly lower in schools, except for formaldehyde and hexaldehyde, which had concentrations equivalent to those found in homes.

The school buildings had less active mold development than the residential buildings. On the other hand, the lead concentration in the dust found at the schools was not statistically lower than those measured in French homes, likewise for the concentration of airborne $PM_{2.5}$.

Depending on the compounds, schools seemed to be less polluted than the homes or to have similar concentrations to those observed in the homes. The differences may be due either to the building characteristics and the activities of the occupants, or to the evolution in the concentrations due to the time elapsed between the two campaigns.

Figure 11. Schools / homes
Comparison of the results from the School (2013-2017) and Home (2003-2005) campaigns for selected pollutants



And in dust? Paint?

Lead in dust

Lead concentrations in settled dust (µg/m²) were determined by dust wiping.

Lead was detected in almost all of the samples.

The median concentration was 7.4 µg/m².

The value of 70 µg/m², recommended by the High Council for Public Health (HCSP) to trigger screening for childhood lead poisoning, was exceeded in 2.4% of the schools. The value of 25 µg/m², recommended by the HCSP within the context of an old housing unit for the purpose of providing hygiene and diet advice to families, was exceeded in 9.6% of the schools.

In the literature, only one study conducted in schools built before 1970 in an underprivileged neighborhood of Philadelphia, used wipes;[4] the lead concentrations were much higher than those found in France.

The data for other metals and SVOCs in dust are being processed.

Lead is still in paint

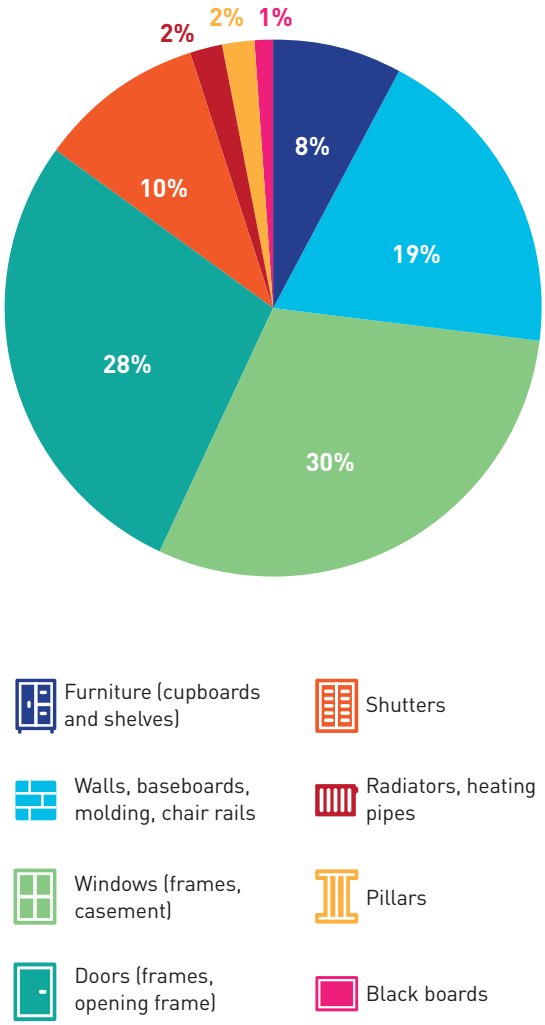
Lead in old paint is a major cause of childhood lead poisoning.

Deteriorated lead-based paint release highly lead contaminated chips and dust, which can be easily ingested by young children, either directly through chips, or indirectly through dust carried to the mouth via the hands.

10% of the schools had at least one measurement of lead in deteriorated paint exceeding the regulatory limit of 1 mg/cm².[5]

This value is not a threshold for health risks, but it makes it possible to identify building components requiring repair. Windows and doors represented more than half of the components that were damaged, with concentrations exceeding 1 mg/cm², followed by walls in approximately 20% of the measurements *(Figure 12)*.

Figure 12. Lead in paint
Distribution of building components with deteriorated paint containing more than 1 mg/cm² of lead (n=15,470 measurements)



[4] Shorten CV and Hooven MK. Methods of exposure assessment: lead-contaminated dust in Philadelphia schools. *Environ Health Perspect* 2000; 108: 663-666.

[5] This threshold is defined by the order of April 25, 2006 relative to the building audit for risk of lead exposure (CREP) (Article 3).

Humidity and mold

20% of the classrooms presented at least one sign of humidity: visible mold, moldy odor, damp stains, visible moisture, persistent condensation or rising damp. The fungal contamination index developed by the CSTB[6] was calculated for each classroom. **16% of the schools had at least one classroom with active fungal contamination.** No significant difference was found between the types of school: nursery school or elementary school.

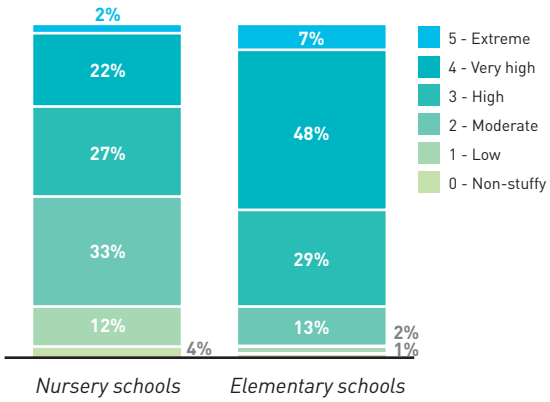
Ventilation

In three-quarters of the schools, there is no mechanical ventilation system; ventilation of schools is operated by opening the windows. The quality of ventilation in a room can be assessed by the air stuffiness level of the room. Air stuffiness represents the adequacy of air renewal of a room with its metabolic load, i.e. the carbon dioxide (CO_2) amount emitted by the breathing of the people in the room. **The air stuffiness ICONE index** is calculated on the basis of the CO_2 concentrations measured when the children are in the classroom. It ranges from 0 (no stuffy air) to 5 (extreme stuffiness). **5% of the schools had at least one classroom with extreme air stuffiness,** specifically an ICONE index of 5, a value for which further investigations must be carried out under current regulations. 36% of the schools had at least one classroom with very high air stuffiness. The proportions according to the type of school are given in *Figure 13*.

ICONE Indoor air stuffiness index	Frequency of CO_2 concentrations
0 = non-stuffy air	100% CO_2 values < 1000 ppm
1 = low	~ 1/3 values > 1000 ppm but < 1700 ppm
2 = moderate	~ 2/3 values > 1000 ppm but < 1700 ppm
3 = high	~ 2/3 values > 1000 ppm of which 1/3 > 1700 ppm
4 = very high	~ 2/3 values > 1700 ppm
5 = extreme	100 % of the values > 1700 ppm

Relations between the ICONE index and the CO_2 concentrations

Figure 13. Distribution of air stuffiness index (ICONE) according to the type of school



Value of the highest ICONE index per school

[6] Moularat S. *et al*. Detection of fungal development in a closed environment through the identification of specific VOC: Demonstration of a specific VOC fingerprint for fungal development. *Sci Total Environ* 2008; 407: 139-146.

In brief

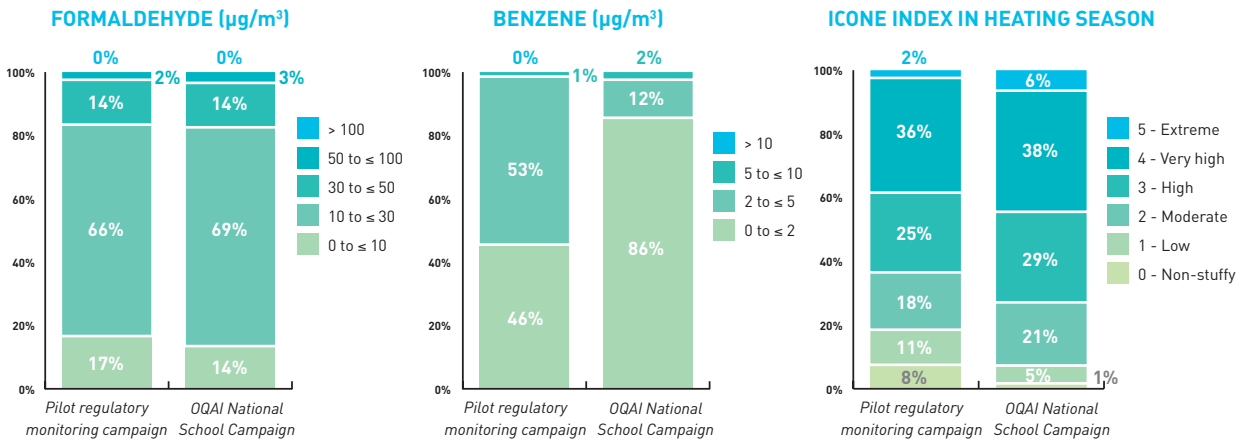
The preliminary data of this large-scale campaign provide precious knowledge about the quality of the indoor environments of the schools in France. Based on the information processed so far, these data show that the indoor air quality in French schools **is quite satisfactory overall**. Indeed, most of the schools are in compliance with the regulatory guideline values for formaldehyde and benzene, and the limit values requiring further investigations and reporting to the local authorities were never exceeded.
However, **four areas of concern emerged, specifically, particles, semi-volatile organic compounds (SVOCs), lead in paint and air stuffiness**. Particulate pollution with $PM_{2.5}$ was omnipresent, with concentrations higher than the guideline value recommended by the WHO in 2005 in almost all of the classrooms. Numerous SVOCs were measured in the air, including some phthalates, PAHs (polycyclic aromatic hydrocarbons) and lindane, which were ubiquitous. The presence of lead in damaged paint at concentrations higher than the regulatory threshold was observed in 10% of the schools. Finally, 41% of the schools had at least one classroom that was very stuffy (ICONE 4 or 5). Regulatory monitoring of air in schools, which requires an assessment of the ventilation and draws attention to the issue of air stuffiness should make it possible to raise the awareness of the managers and occupants of school buildings and thereby improve the situation in the future.

Prospects

The data continue to be processed, with the study of metals and SVOCs in floor settled dust as well as the exposure of children to electromagnetic fields. The thermal comfort, acoustics and lighting will also be studied. Further statistical analyses will focus on:

- the relations between indoor and outdoor air pollution;
- the determinants of indoor pollution in classrooms and the development of predictive models of concentration;
- the identification of multi-pollution situations: cross-analysis between the comfort parameters and indoor pollution demonstrating if there are any relation, for example, between noise and indoor pollution and if there are types of buildings in which the indoor environment might need to be improved.

Figure 14. OQAI National School Campaign and pilot study of the regulatory monitoring (2009-2011) Comparison of the results



Acknowledgments

Sepia-Santé for school recruitment

The field investigators: Franck Chaventré Conseil et Etudes, Demouville (14) and Caen Diag, Cahagnes (14); Burgeap, Boulogne (92), Strasbourg (67) ; Econeau'logis, Peillonnex (74); M3E, La Suze-sur-Sarthe (72); Conseil Habitat Santé/Air Paca, Marseille (13); ASPA, Strasbourg (67) ; Air Pays de la Loire, Nantes (44); Atmo-Auvergne/ Lim'Air, Clermont-Ferrand (63), Limoges (87); Enexco, Montpellier (34); Geoluz, Ludon en Médoc (33); CSTB, Champs-sur-Marne (77).

The operators for lead measurements: Caen Diag, Cahagnes (14); Pyramides Conseil, Gennevilliers (92); Gavard-Leroy, Peillonnex (74); Adiante Dic, La Chapelle St Ursin (18); Apave, Marseille (13), Paris (75) ; Adiante Diag, Barr (67); AB Diagnostic, Ernée (53); Socotec, Nancy (54), Lyon (69), Lille (59); Adiante Auvergne, Clermont-Ferrand (63); ASE Expertise/Agexim 83, Le Luc (83).
The laboratories: Eurofins, Saverne (67) ; Laboratoire Central de la Préfecture de Police (LCPP), Paris (75); Ecole des Hautes Etudes en Santé Publique / Laboratoire d'Études et de Recherche en Environnement et Santé, Rennes (35); Service Parisien de Santé Environnement, Paris (75); CSTB, laboratories of Saint Martin d'Hères (38) and Champs-sur-Marne (77)

OQAI NATIONAL SCHOOL CAMPAIGN AT A GLANCE

301 schools surveyed

From **2013** to **2017**
in **245** towns
from **31** counties

Representative of more than **50,000** schools in continental France

Screening for 71 pollutants

Including

- **13** volatile organic compounds (VOCs)
- **3** aldehydes
- **46** semi-volatile organic compounds (SVOCs)

And also measurements of air stuffiness, noise, lighting and electromagnetic fields

> 200,000,000 data collected

Observatoire de la qualité de l'air intérieur

The OQAI was created by the public authorities in 2001. It is under the supervision of the ministries in charge of Housing, Environment and Health, ADEME (the French Environment and Energy Management Agency) and the Scientific and Technical Center for Building (CSTB), the scientific and technical operator. The OQAI is supported by public funding from the ministries, ADEME and the French Agency for Food, Environmental and Occupational Health & Safety (ANSES).

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Publication Director: Andrée Buchmann; **Managing Editor:** Séverine Kirchner; **Editorial Committee of Newsletter no. 11**: Claire Dassonville, Corinne Mandin, Sutharsini Sivanantham, Wenjuan Wei, Laeticia Malingre, Anthony Grégoire, Olivier Ramalho, Jacques Ribéron, Mickaël Derbez, Corinne Béra / ISSN: pending

June 2018 - Published by: Luciole - Photo credits: CSTB, Fotolia - Print run of 2000.