



Observatoire de la qualité de
l'air intérieur

CSTB
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Indoor air quality in French schools: a nationwide survey (2013-2017)

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Background and objective

- **IAQ Observatory: created in 2001**
- **Objective: To coordinate and develop indoor air research activities at a national scale**
 - To improve knowledge on IAQ in buildings
 - To provide support for public policies
 - To publish recommendations for professionals and general public
- **School survey started in 2013 to describe indoor environment in a sample of schools representative of the French stock ($\approx 52,000$)**



Sampling design

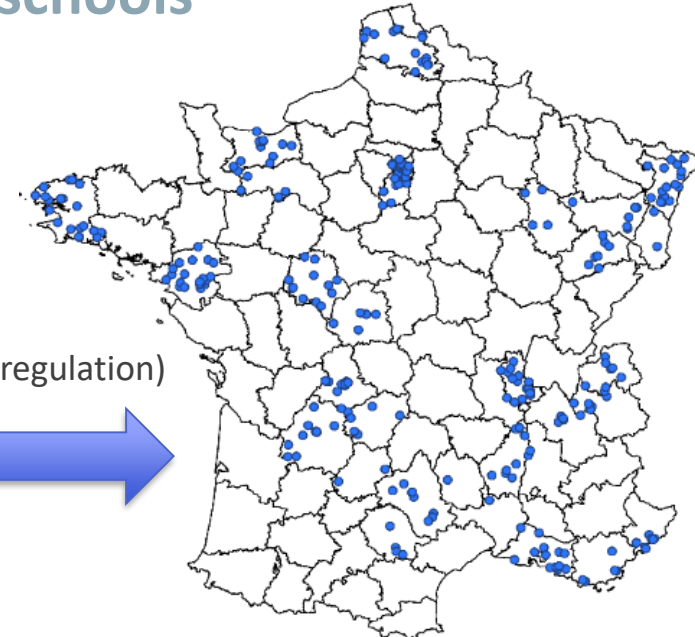


52,582 schools

Randomly selected schools

Stratified on:

- **Schools** (nursery/primary)
- **Environment** (urban/rural)
- **Climatic zones** (French thermal regulation)



301 schools
(600 classrooms)

Number of schools calculated on
the basis of the target precision on
the VOC concentrations

Raking ratio adjustment (Deming and Stephan)



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Parameters (1)

One week: from Monday to Friday

On-line measurements

- ⇒ Carbon dioxide (CO₂)
- ⇒ Temperature and relative humidity
- ⇒ Particle counting (0,3 to 20 µm)
- ⇒ Noise level (7 days, starting the Friday before the monitoring week)

Air samples

- ⇒ **With pumps:** PM_{2,5} and SVOCs
- ⇒ **With passive samplers:**
 - VOCs and aldehydes
 - Nitrogen dioxide (NO₂)





Parameters (2)

Dust sampling

- ⇒ With a wipe for lead
- ⇒ With a specific vacuum cleaner: metals and SVOCs



Punctual measurements

- ⇒ Illuminance on tables and boards (illuminance meter)
- ⇒ Lead in paint by X-Ray fluorescence
- ⇒ Electromagnetic fields



Questionnaires

- ⇒ Description of the classrooms and the buildings
- ⇒ Description of classroom activities
- ⇒ Teachers' and children's perception (noise, light, thermal comfort)





Results at a glance

Positive aspects

- Low NO₂ concentrations
- Lower VOC concentrations compared to dwellings

Critical issues

- PM_{2,5}
- Semi-volatile organic compounds
- Lack of ventilation, air stuffiness
- Lead in paint



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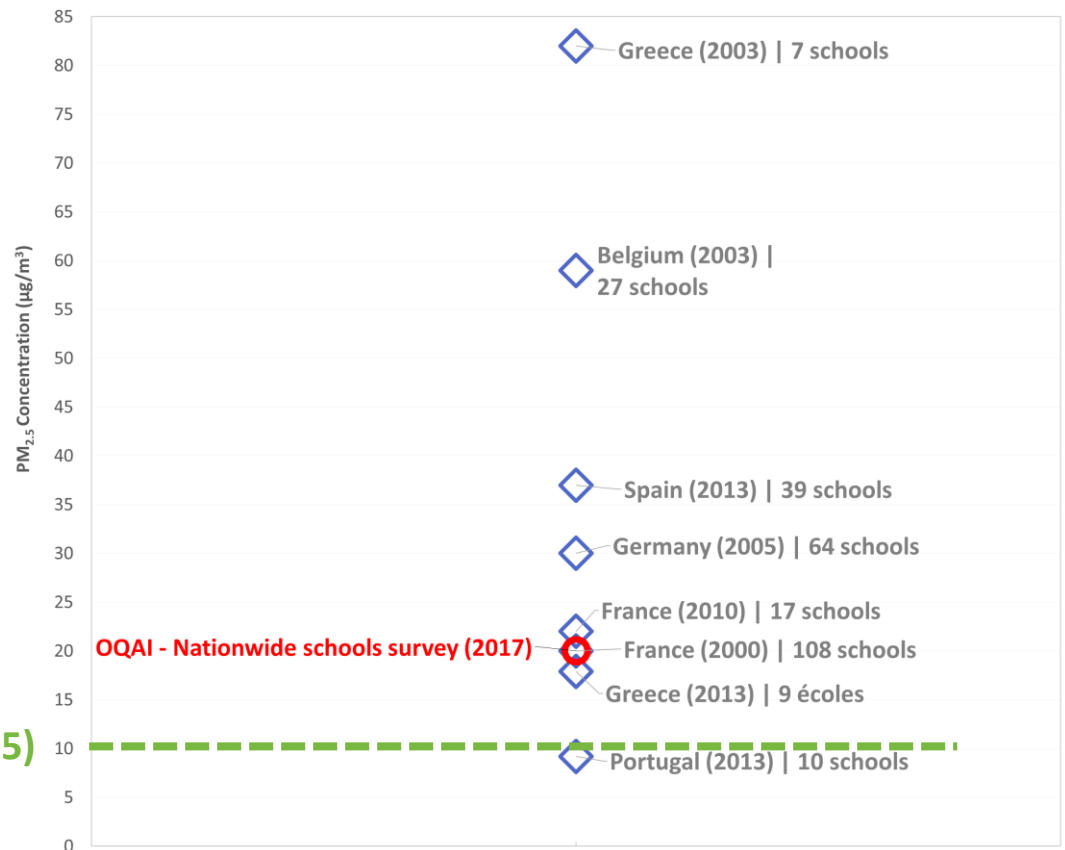
Particles PM_{2.5}

Median = **18 µg/m³**

Mean (SD) = **20 ± 1 µg/m³**

96% of schools > 10 µg/m³, WHO guideline value for outdoor air applicable to indoor air (WHO AQGs, 2005)

WHO (2005)



Mean concentrations of PM_{2.5} measured in European schools since 2010



Semi-volatile organic compounds

46 target SVOCs

(gas and particulate phases)

- 16 pesticides :
organochlorine,
organophosphorous,
pyrethroids
- 2 synthetic musks (AHTN,
HHCB)
- 7 polycyclic aromatic
hydrocarbons (PAHs)
- 9 polychlorobiphenyls
(PCBs)
- 6 phthalates
- 6 brominated flame
retardants (PBDEs)

SVOCs	% > LOD	Median ng/m ³
4,4'-DDT	15%	<LOD
α-HCH	94%	0,2
δ-HCH (lindane)	100%	1,4
α-endosulphan	63%	<LOQ
Chlorpyriphos-éthyl	46%	<LOD
Permethrin	6%	<LOD
Tributylphosphate	96%	3,8
Acenaphtene	100%	1,9
Benzo[a]pyrene	45%	<LOD
Fluoranthene	100%	0,7
Fluorene	100%	7,5
Phenanthrene	100%	11,6
HCCB	100%	148
AHTN	100%	21,1
DBP	99%	168
DEHP	6%	<LOD
DiBP	100%	790
DiNP	43%	<LOD
PCB 31	88%	0,1
PCB 52	97%	0,2
PCB 180	3%	<LOD
BDE 47	7%	<LOD
BDE 153	0%	<LOD



Ventilation – Air exchange

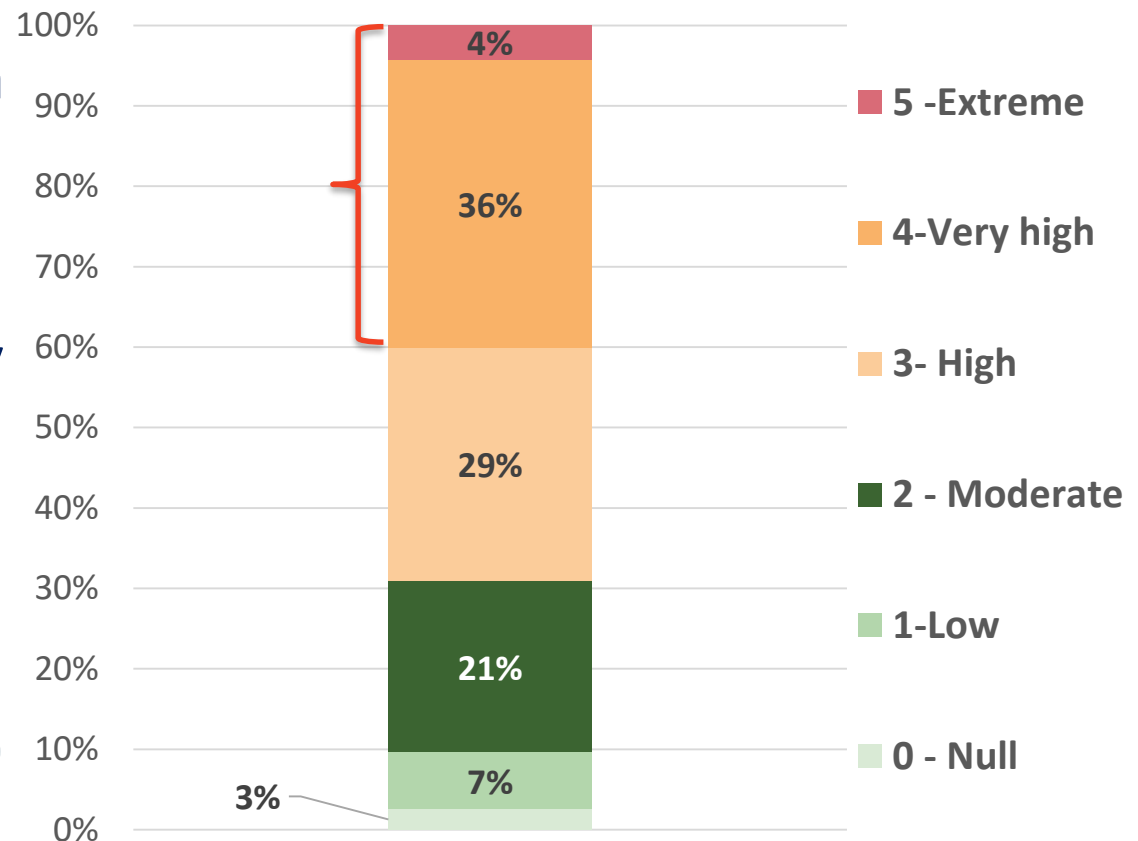
29% of schools have a least one classroom with a mechanical ventilation system

Windows are not regularly open

40% of schools have at least one classroom with a very high ICONE index (≥ 4)

Air stuffiness index (ICONE)

(Canha et al, Indoor Air, 2016)

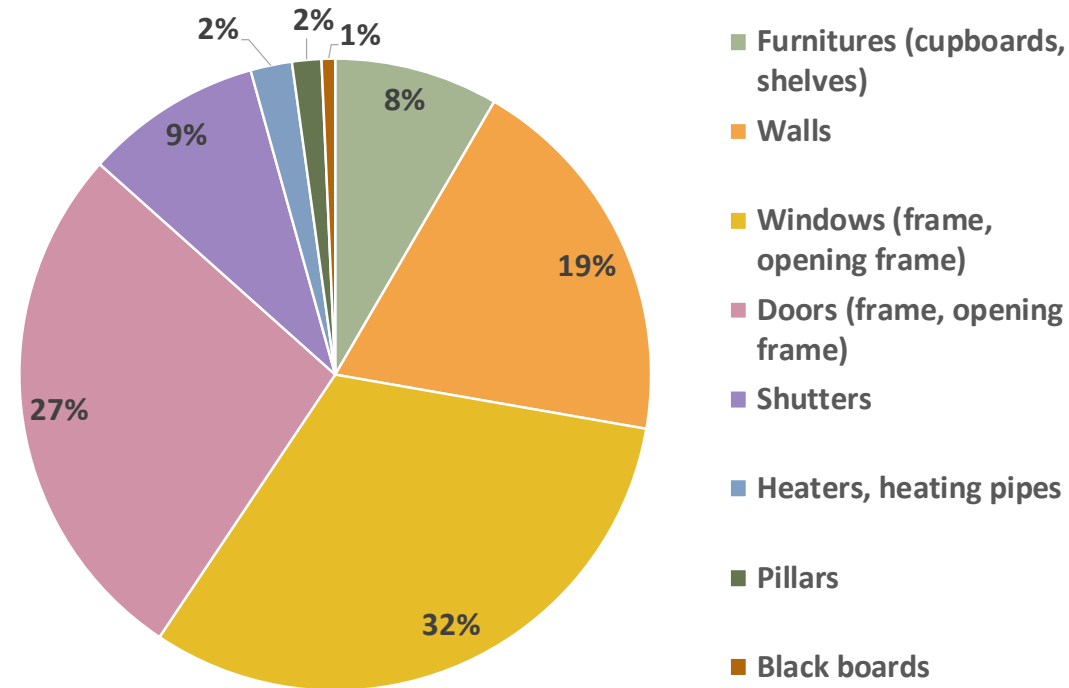


Highest value per school among the instrumented classrooms



Lead in paint

15% of schools have at least one classroom with deteriorated paint containing more than 1 mg/cm² of lead

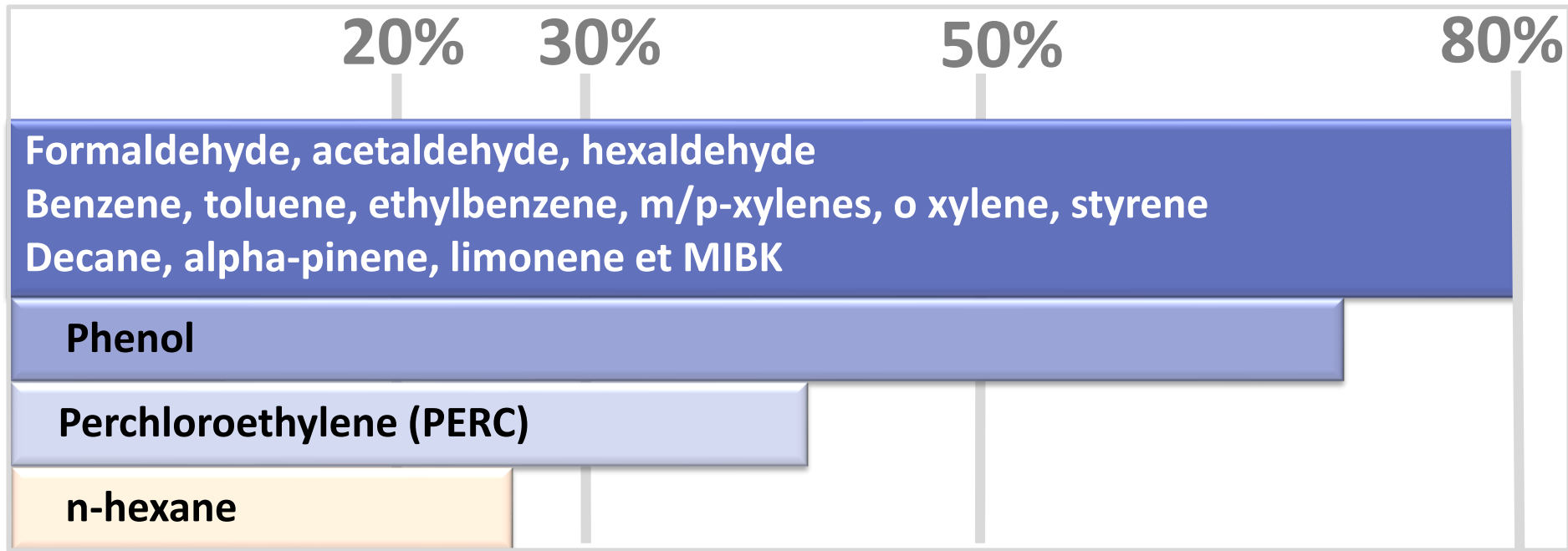


N=28 487 measurements



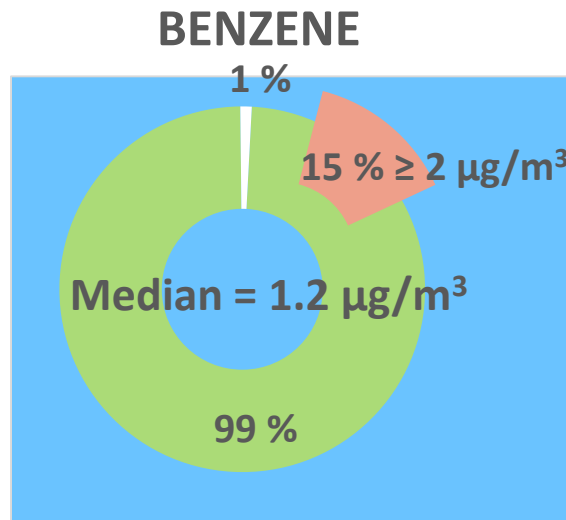
Volatile organic compounds and aldehydes

Frequencies of detection

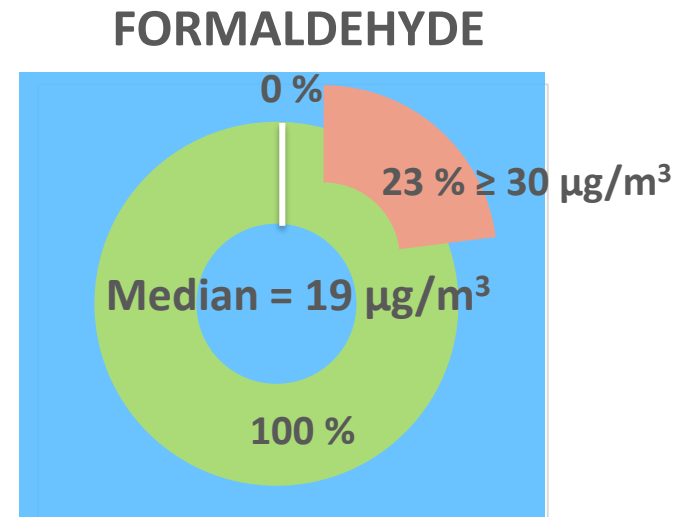




Volatile organic compounds and aldehydes



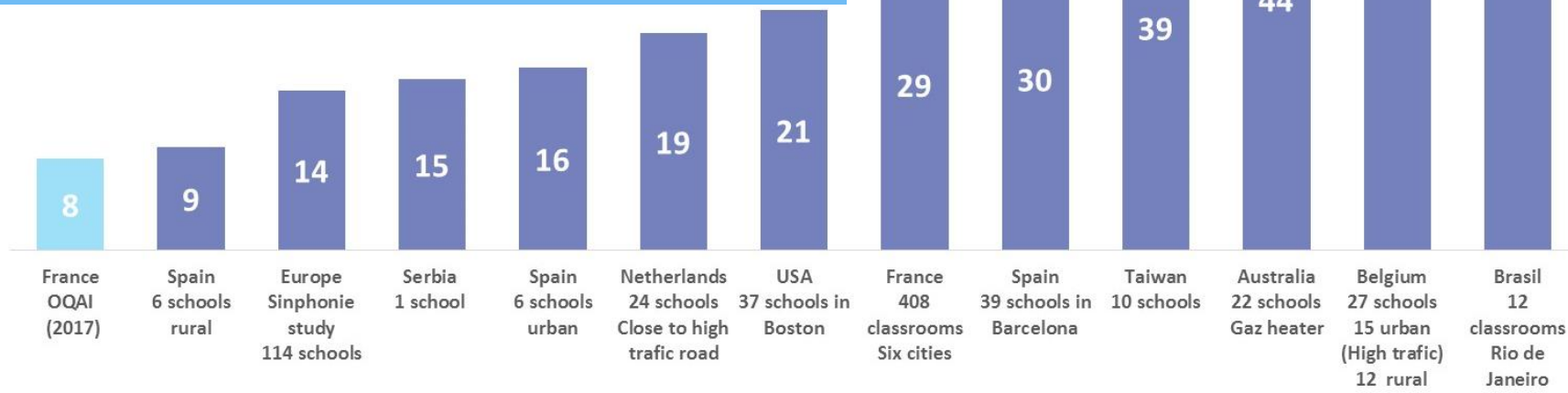
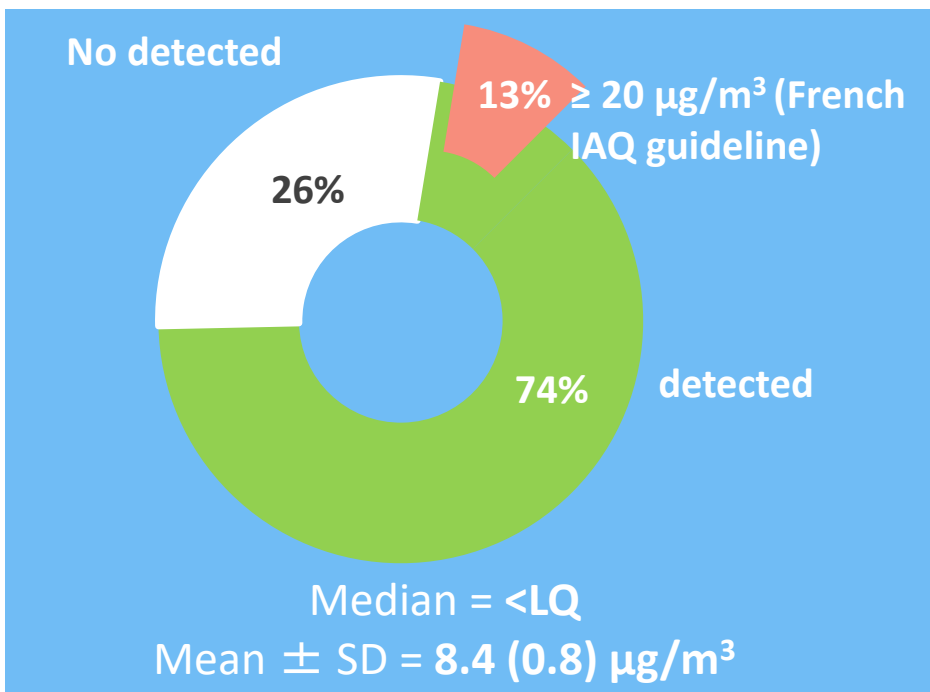
IAQ guideline value
 $2 \mu\text{g}/\text{m}^3$



IAQ guideline value
 $30 \mu\text{g}/\text{m}^3$



Nitrogen dioxide (NO₂)





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Compared to dwellings?

Comparison with IAQ Observatory nationwide study in dwellings (2003-2005)

Concentrations

Schools < Dwellings (*p-value*<0.05)

Except for formaldehyde and PM_{2,5}

Compared to dwellings?

Comparison with IAQ Observatory nationwide study in dwellings (2003-2005)

SVOCs concentrations

Schools > Dwellings ($p < 0.05$)

SVOCs		Schools	Dwellings
Musks	HCCB	148	5,7
	HTNA	21,1	2,4
PCBs	PCB28	0,1	0
	PCB31	0,1	0
	PCB52	0,2	0
	PCB101	0,1	0
Phthalates	BBP	<LOQ	17
	DBP	168	33
	DEP	286	297
	DiBP	790	99

Schools ~ Dwellings

SVOCs		Schools	Dwellings
Pesticides	α -endosulphan	<LOQ	0,1
	α -HCH	0,2	0,4
	δ -HCH (lindane)	1,4	0,6

Schools < Dwellings ($p < 0.05$)

SVOCs		Schools	Dwellings
PAHs	Anthracene	0,5	1,4
	Fluoranthene	0,7	2
	Fluorene	7,5	16
	Phenanthrene	11,6	8,3
	Pyrene	<LOD	0,8





Conclusion

An extensive database about the school environment

Indoor air quality in French schools is quite good

- Most of the schools meet the French formaldehyde and benzene regulatory IAQ guidelines
- French children less exposed at school than at home

4 issues that need further attention

- $PM_{2,5}$
- Semi-volatile organic compounds in air
- Lead in paint
- Lack of ventilation, air stuffiness



Data analysis still in process...

- Indoor pollution:
 - electromagnetic fields
 - metals and SVOCs in settled dust
 - comfort parameters: thermal comfort, noise, light
- Determinants of indoor pollutants and discomfort
- Cumulative exposure: noise and indoor air pollution



Thank you for your attention!

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- French Agency for the Environment and Energy Management (ADEME)
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⇒ **Thanks to:**

- Field technicians
- Building owners and school directors
- Teachers and pupils

