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School children's exposure to ultrafine particles: a cross-sectional study in rural and urban sites

Joana Madureira, João Rufo, Inês Paciência, Lívia Aguiar, André Moreira, Eduardo de Oliveira Fernandes and João Paulo Teixeira*

*WG Member

National Health Institute / Portugal

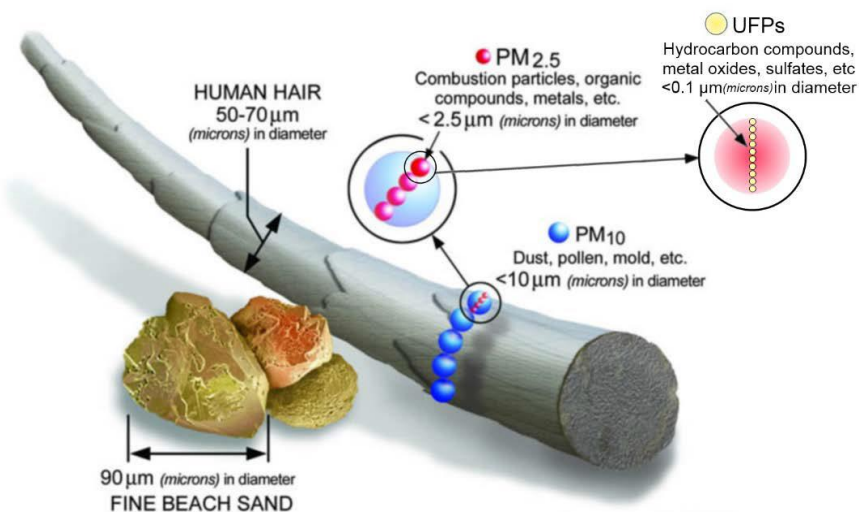
jpft12@gmail.com

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Scientific context

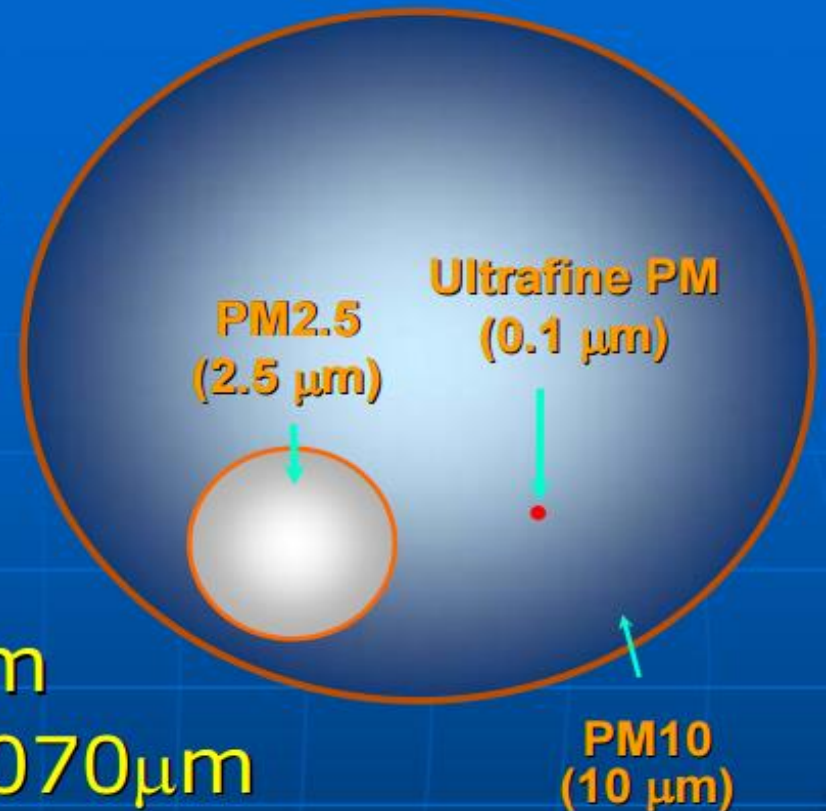
- Mixture of solid or solid/liquid particles suspended in air.
- Considerable variation in origin, size, shape, chemical properties.
- Commonly described by aerodynamic diameter.
- Ultrafine particles (UFPs, $<0.1\mu\text{m}$) are among the most toxic pollutants in the outdoor and indoor environments.



Scientific context

Relative particle size

- Ultrafine Particles: less than $0.1\mu\text{m}$
- Viruses: $0.002 - 0.070\mu\text{m}$
- Bacteria: $3 - 50\mu\text{m}$
- Red Blood Cell: $7.5\mu\text{m}$
- Human Hair: $60\mu\text{m}$





Scientific context

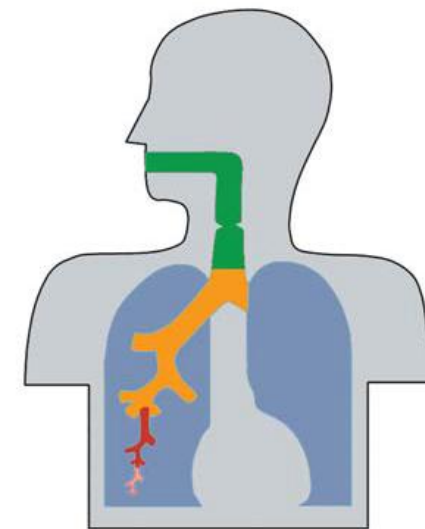
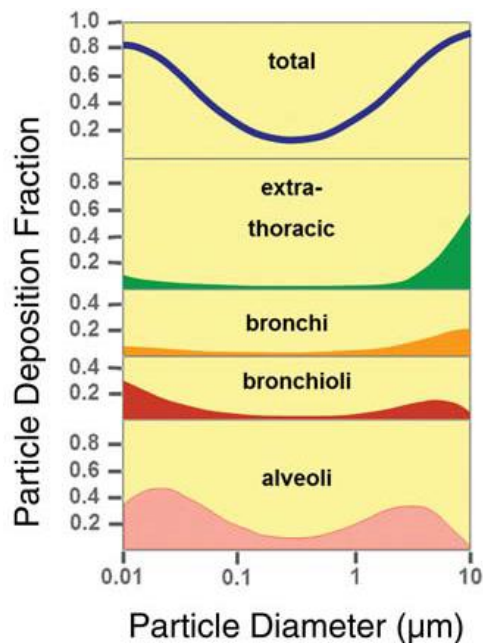
Why are we concerned about UFPs?

Contain little mass, but:

- Possess a large surface area and very high number concentration
- Have a high deposition rate in the lung
- Can enter the circulatory system and move from the lungs to other organs
- Contain toxic components
- May initiate harmful oxidant injury

Scientific context

- UFPs main sources (both outdoors and indoors):
 - combustion process (wood fires, car engines, industry, cooking fumes and cigarette smoke, etc.)
 - secondary reactions
 - sand dust, fires, diesel smoke, sea salt
- Health risks of UFPs (both size and chemical composition):
 - Lung function loss
 - Asthma
 - COPD
 - Cancer



Scientific context

PM₁₀:

20 µg/m³ (annual mean)

50 µg/m³ (24-hour mean)

PM_{2.5}:

10 µg/m³ (annual mean)

25 µg/m³ (24-hour mean)

UFPs:

?

WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide. 2005.

- Exposure to UFPs may lead to consequences in children due to their increased susceptibility when compared to older individuals.



Scientific context

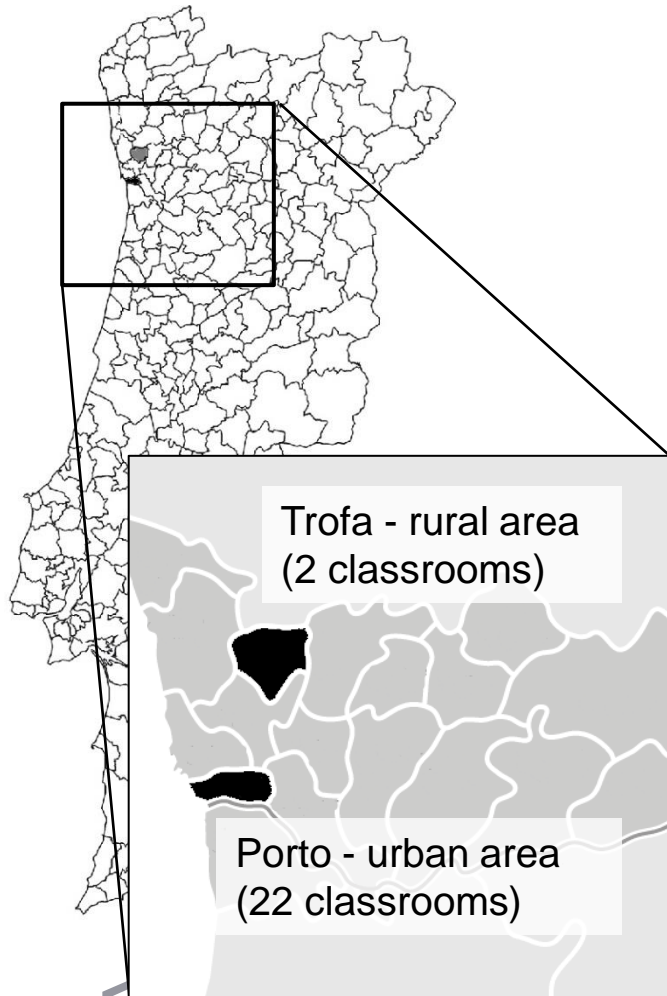
- Scientific information for UFPs is limited:
 - UFPs concentrations do not correlate well with PM_{10} or $PM_{2.5}$ mass concentrations
 - UFPs concentrations decrease rapidly with distance from source
- Indoor sources can be important to UFP exposure (e.g. combustion sources and terpene/ozone reactions).
- There are no studies assessing children exposure to UFPs in urban and rural primary schools in Portugal, where they spend a substantial fraction of their time.

Objectives

- To assess the indoor UFP number concentrations in urban and rural Portuguese primary schools.
- To investigate the trends of UFP number concentrations in classrooms with distinct characteristics.
- To evaluate the influence of outdoor air on UFP number concentrations in the indoor environment.



Material and methods



- 8 primary schools (naturally ventilated)
 - 6 located in an urban area
 - 2 located in a rural area
- Walkthrough inspection & checklist
- Indoor and outdoor sampling
 - 1-4 classrooms/school
 - 1 outdoor/school

(regular activities and representative conditions of occupancy and use of classrooms)
- Winter time (January-February/2014)

Material and methods

Walkthrough inspection and checklist

Checklist

1. Outdoor Characterization

1.1. Geographical location

Interior		Additional comments
Seacoast		
North of the country		
South of the country		
East of the country		
West of the country		

1.2. Building location

Industrial area		Additional comments
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Time-activity diary

Professores

Número total de alunos na sala de aula: | Condições meteorológicas externas

Aulas	Nº alunos na sala	Janelas	Portas	Aquecimento	Atividades laborativo	Tarefas	Cozinha	Leitura, escrita	Outras (especificar)
	(q, assinala no 5)	(q, assinala uma das opções)	(q, assinala uma das opções)						

1.2. Building location

		Additional comments
Industrial area		
Mixed industrial/residential area		

(...)

3.1. Type of general ventilation strategy

		Additional comments
Natural		
Natural assisted (exhaustion)		
Mechanical		

(...)

4.1. Water leakage or flooding in the last 12 months (if yes, specify the date)

		Additional comments
No		
Yes		
Roof	/ /	

Material and methods

Indoor and outdoor sampling



Portable condensation particle counters (P-Track model 8525, TSI Inc., MN, USA)



CO₂ , temperature and relative humidity monitor (IAQ-CALC monitor model 7545, TSI Inc., MN, USA)

Indoors and outdoors	Location	Indoors and outdoors
1 min	Logging intervals	5 min
at least 8h (from 9 am to 5 pm)	Measurement time	24/day

Material and methods

Main building/classrooms characteristics

Characteristics No. of classrooms

Meals are cooked in the school		4
Floor level	0	11
	1	13
Standard board type	Chalk	8
	White	16
Classrooms with a sink		13
Floor covering material	Synthetic	17
	Wood	7
Suspended ceiling		7
Type of window glazing	Single	11
	Double	13
Curtains standard material	Textile	20
	Laminated	4
Heaters power source	Gas	2
	Electricity	22
Condensation on the windows		17



Results - UFPs indoor and outdoor levels

Schools	Indoor (pt/cc)			Outdoor (pt/cc)		
	Mean	Min	Max	Mean	Min	Max
U 1	4.7×10^3	1.1×10^3	1.4×10^4	2.2×10^3	0.6×10^3	6.5×10^3
U 2	7.1×10^3	3.7×10^3	2.1×10^4	8.0×10^3	3.8×10^3	2.0×10^4
U 3	7.4×10^3	2.2×10^3	6.9×10^4	1.9×10^3	3.6×10^3	1.4×10^5
U 4	7.4×10^3	2.4×10^3	3.3×10^4	3.3×10^3	1.2×10^3	8.7×10^3
U 5	1.7×10^4	3.4×10^3	1.5×10^5	8.8×10^3	3.3×10^3	4.4×10^4
U 6	1.6×10^4	3.0×10^3	4.3×10^5	1.0×10^4	3.8×10^3	2.4×10^4
R 1	7.8×10^3	3.0×10^3	1.4×10^4	5.6×10^3	0.7×10^3	2.1×10^4
R 2	4.0×10^3	2.3×10^3	1.4×10^4	6.1×10^3	1.4×10^3	3.5×10^4
U total	1.0×10^4	1.1×10^3	4.3×10^5	9.0×10^3	5.6×10^2	1.4×10^5
R total	5.7×10^3	2.3×10^3	1.4×10^4	5.9×10^3	6.5×10^2	3.5×10^4

U – Urban School; R – Rural School

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U 5	1.7×10^4	3.4×10^3	1.5×10^5	8.8×10^3	3.3×10^3	4.4×10^4
U 6	1.6×10^4	3.0×10^3	4.3×10^5	1.0×10^4	3.8×10^3	2.4×10^4
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R 2	4.0×10^3	2.3×10^3	1.4×10^4	6.1×10^3	1.4×10^3	3.5×10^4
U total	1.0×10^4	1.1×10^3	4.3×10^5	9.0×10^3	5.6×10^2	1.4×10^5
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$p < 0.01$

U – Urban School; R – Rural School

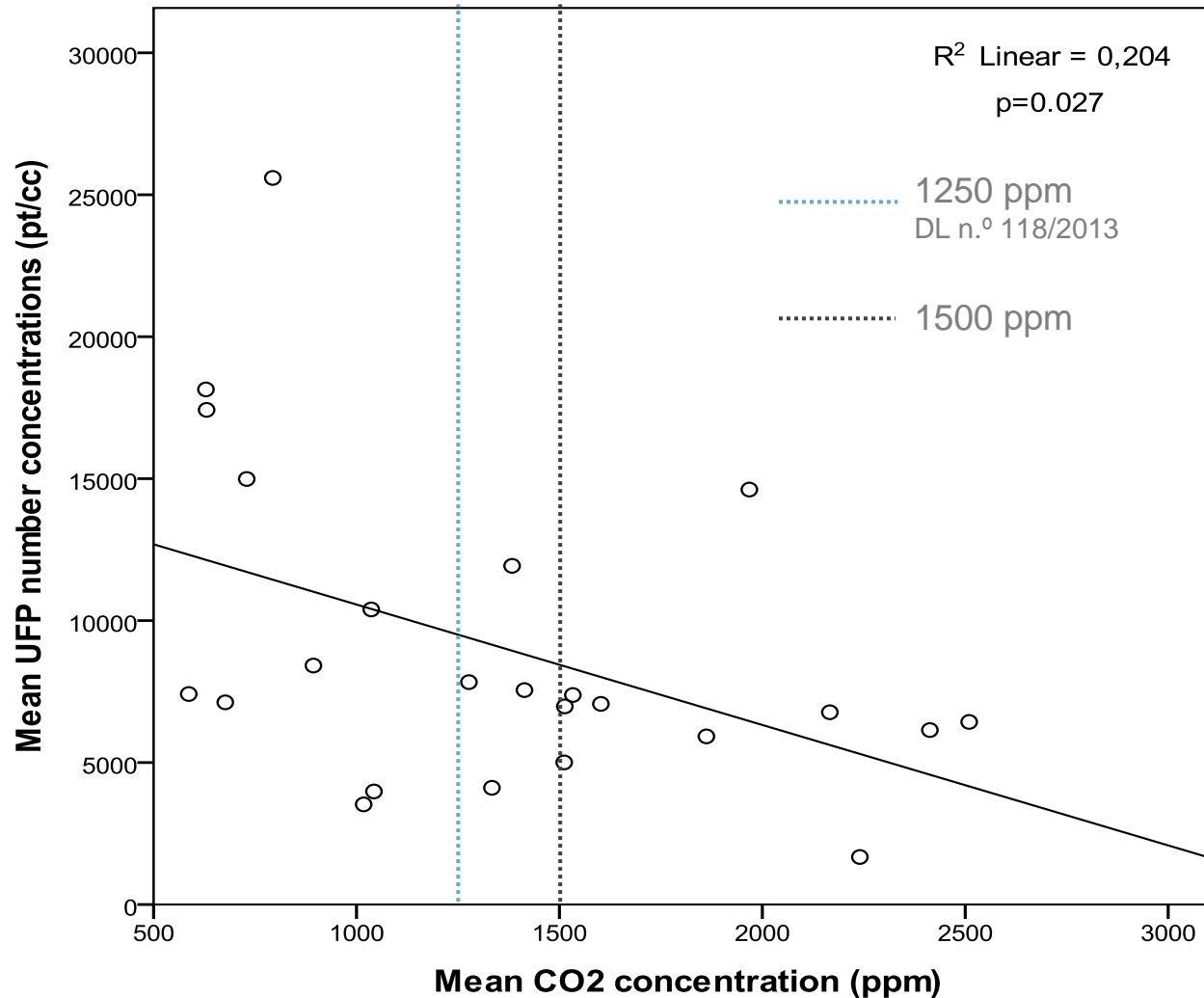
Results - UFPs levels vs bldg. characteristics

Classroom characteristics		No. of classrooms	Mean UFP (pt/cc)	<i>p</i>
Density of occupation (m ² /occupant)	≤ 2.5	15	9.0 × 10 ³	<0.001
	> 2.5	9	11.5 × 10 ³	
Classroom location	Ground floor	11	11.8 × 10 ³	<0.001
	First storey	13	8.6 × 10 ³	
Standard board type	White board	16	8.7 × 10 ³	<0.001
	Chalk board	8	13.1 × 10 ³	
Classroom provided with a sink?	No	11	10.4 × 10 ³	0.055
	Yes	13	9.9 × 10 ³	
Wood as furniture material?	No	4	5.4 × 10 ³	<0.001
	Yes	20	11.2 × 10 ³	
Floor covering material	Synthetic	17	9.5 × 10 ³	<0.001
	Wood	7	12.5 × 10 ³	
Window frame material	Aluminium	21	10.4 × 10 ³	0.072
	Metal	3	7.1 × 10 ³	
Type of window glazing	Single	11	7.3 × 10 ³	<0.001
	Double	13	12.1 × 10 ³	
Curtains standard material	Textile	20	8.9 × 10 ³	<0.001
	Metallic	4	16.1 × 10 ³	
Heaters power source	Electricity	22	10.8 × 10 ³	<0.001
	Gas	2	4.7 × 10 ³	
Meals are cooked in the school	No	20	8.5 × 10 ³	<0.001
	Yes	4	17.1 × 10 ³	
Floors vacuum frequency	Daily	6	6.6 × 10 ³	<0.001
	Once a week	4	16.1 × 10 ³	

Results - UFPs levels vs bldg. characteristics

Classroom characteristics		No. of classrooms	Mean UFP (pt/cc)	<i>p</i>
Density of occupation (m ² /occupant)	≤ 2.5	15	9.0 × 10 ³	<0.001
	> 2.5	9	11.5 × 10 ³	
Classroom location	Ground floor	11	11.8 × 10 ³	<0.001
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Standard board type	White board	16	8.7 × 10 ³	<0.001
	Chalk board	8	13.1 × 10 ³	
Floors vacuum frequency	Daily	6	6.6 × 10 ³	17<0.001
	Once a week	4	16.1 × 10 ³	

Results – influence of outdoor air (urban sites)





Final remarks

- ✓ Indoor UFPs are present in higher concentrations in urban environments when compared to rural environments.
- ✓ In urban schools, indoor UFP number concentrations were higher than outdoor concentrations, *suggesting that indoor sources significantly contribute to the mean indoor UFP concentrations.*
- ✓ The outdoor environment may have a major impact on indoor UFP number concentrations.



Final remarks

- ✓ However, CO₂ levels were inversely correlated with UFP number concentrations, *outdoor environment has a large influence on the indoor UFP concentrations.*

- ✓ Some school/classroom characteristics may influence higher indoor UFP number concentrations, such as:
 - Cooking meals in schools
 - Presence of chalk boards
 - Classroom located on the ground floor

- ✓ The present findings may contribute to understand and elaborate preventive strategies to reduce indoor air pollution in primary schools caused by UFPs.



Perspectives towards the future

- ✓ The number of rural schools should be extended in a future study to better support and understand the magnitude of the differences between schools in different environments.
- ✓ Further studies on secondary reactions should be carried out.

Project research team and funding



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School children's exposure to ultrafine particles: a cross-sectional study in rural and urban sites

Thank you!

João Paulo Teixeira

WG Member

National Health Institute / Portugal

jpft12@gmail.com

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Publications

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EXPOSURE OF CHILDREN TO ULTRAFINE PARTICLES IN PRIMARY SCHOOLS IN PORTUGAL

João Cavaleiro Rufo¹, Joana Madureira¹, Inês Paciência¹, Klara Slezakova², Maria do Carmo Pereira², Cristiana Pereira³, João Paulo Teixeira³, Mariana Pinto⁴,

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Indoor air quality in Portuguese schools: levels and sources of pollutants

Abstract Indoor air quality (IAQ) parameters in 73 primary classrooms in Porto were examined for the purpose of assessing levels of volatile organic compounds (VOCs), aldehydes, particulate matter, ventilation rates and bioaerosols within and between schools and potential sources. Levels of VOCs

**J. Madureira¹, I. Paciência¹,
C. Pereira², J. P. Teixeira^{2,3},
E. de O. Fernandes¹**