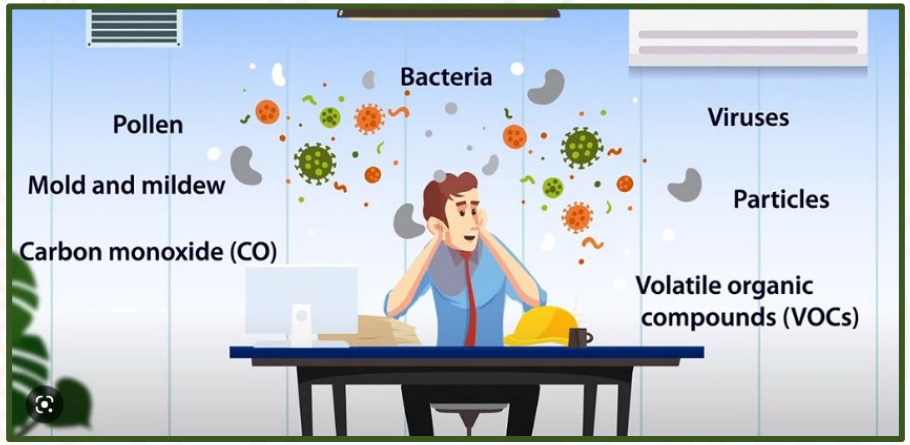
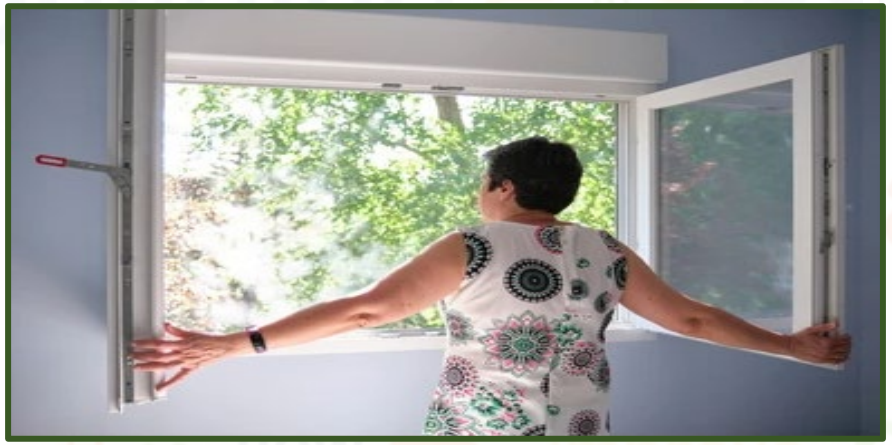
PARQUE CIENTÍFICO Y TECNOLÓGICO DE CASTILLA - LA MANCHA

ICCA
INSTITUTO DE INVESTIGACIÓN EN COMBUSTIÓN Y CONTAMINACIÓN ATMOSFÉRICA



CONTAMINACIÓN DEL AIRE INTERIOR, ¿REALMENTE SOMOS CONSCIENTES?



Dra. Florentina Villanueva. Investigadora Programa INCRECYT
Parque Científico y Tecnológico de Castilla-La Mancha
Instituto de Investigación en Combustión y Contaminación Atmosférica.
GRUPO DE QUÍMICA Y CONTAMINACIÓN ATMOSFÉRICA (QYCA)
Universidad de Castilla La Mancha.
Florentina.garcia@uclm.es ; Twitter: @FloriVilla3

16 de noviembre de 2022. II Jornada Regional de Educación en Ciencias, Tecnología e Ingeniería

CONTAMINACIÓN ATMOSFÉRICA

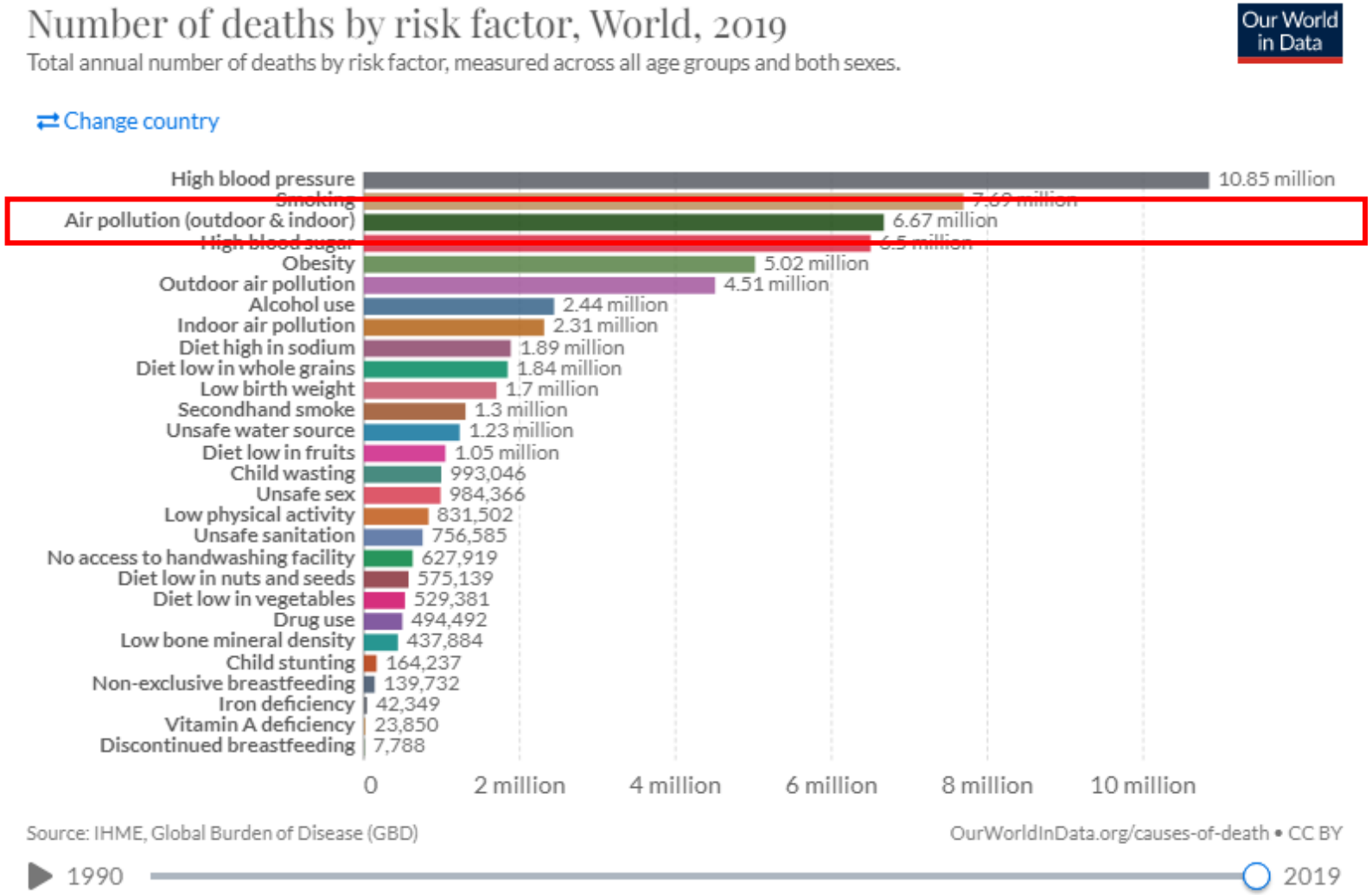
Imagen de la boina de contaminación de Madrid. EFE

Fuente: El confidencial de Ciudad Real

PARQUE CIENTÍFICO Y TECNOLÓGICO DE CASTILLA - LA MANCHA

ICCA INSTITUTO DE INVESTIGACIÓN EN COMBUSTIÓN Y CONTAMINACIÓN ATMOSFÉRICA

CONTAMINACIÓN DEL AIRE INTERIOR Y SALUD



PARQUE CIENTÍFICO
Y TECNOLÓGICO
DE CASTILLA - LA MANCHA

¿POR QUÉ DEBEMOS PREOCUPARNOS POR LA CALIDAD DEL AIRE INTERIOR?

1 **90%** De nuestro tiempo lo pasamos en el interior

2 **2-5x** Mas contaminación dentro que fuera

3

Un adulto inhala 33 kg aire por día ($27m^3 x 1,225 kg/m^3$)
2 kg líquidos y 2,5 kg comida

Se aplica a ambientes de interiores no industriales: edificios de oficinas, edificios públicos (colegios, restaurantes, lugares de ocio, etc) y viviendas particulares

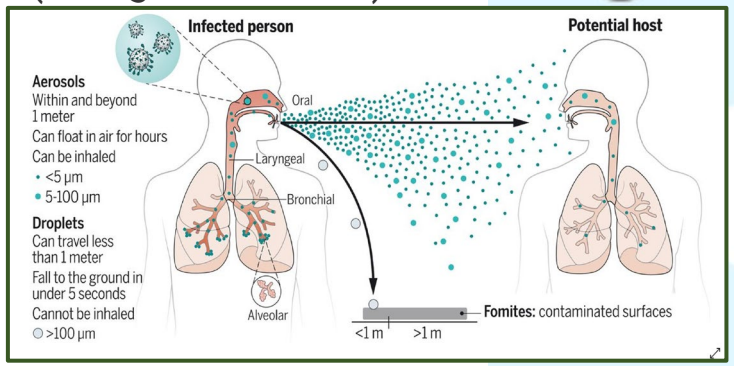
PARQUE CIENTÍFICO
Y TECNOLÓGICO
DE CASTILLA - LA MANCHA

¿POR QUÉ DEBEMOS PREOCUPARNOS POR LA CALIDAD DEL AIRE INTERIOR?

1 **90%** De nuestro tiempo lo pasamos en el interior

2 **2-5x** Mas contaminación dentro que fuera

(Wang et al., 2021)



Airborne transmission of respiratory viruses: including SARS-CoV, MERS–CoV, influenza virus and respiratory syncytial virus

Contaminantes Comunes del aire interior

INTERIOR
CO_2
Respiración, cocinar, estufas

Partículas
PM10
PM2.5
UFP
Tubos de escape, polvo, otras fuentes

INTERIOR
COVs
Pinturas, cocinar, fumar, productos de limpieza, ambientadores etc

INTERIOR
Formaldehído
Materiales construcción, muebles, cocinar y fumar

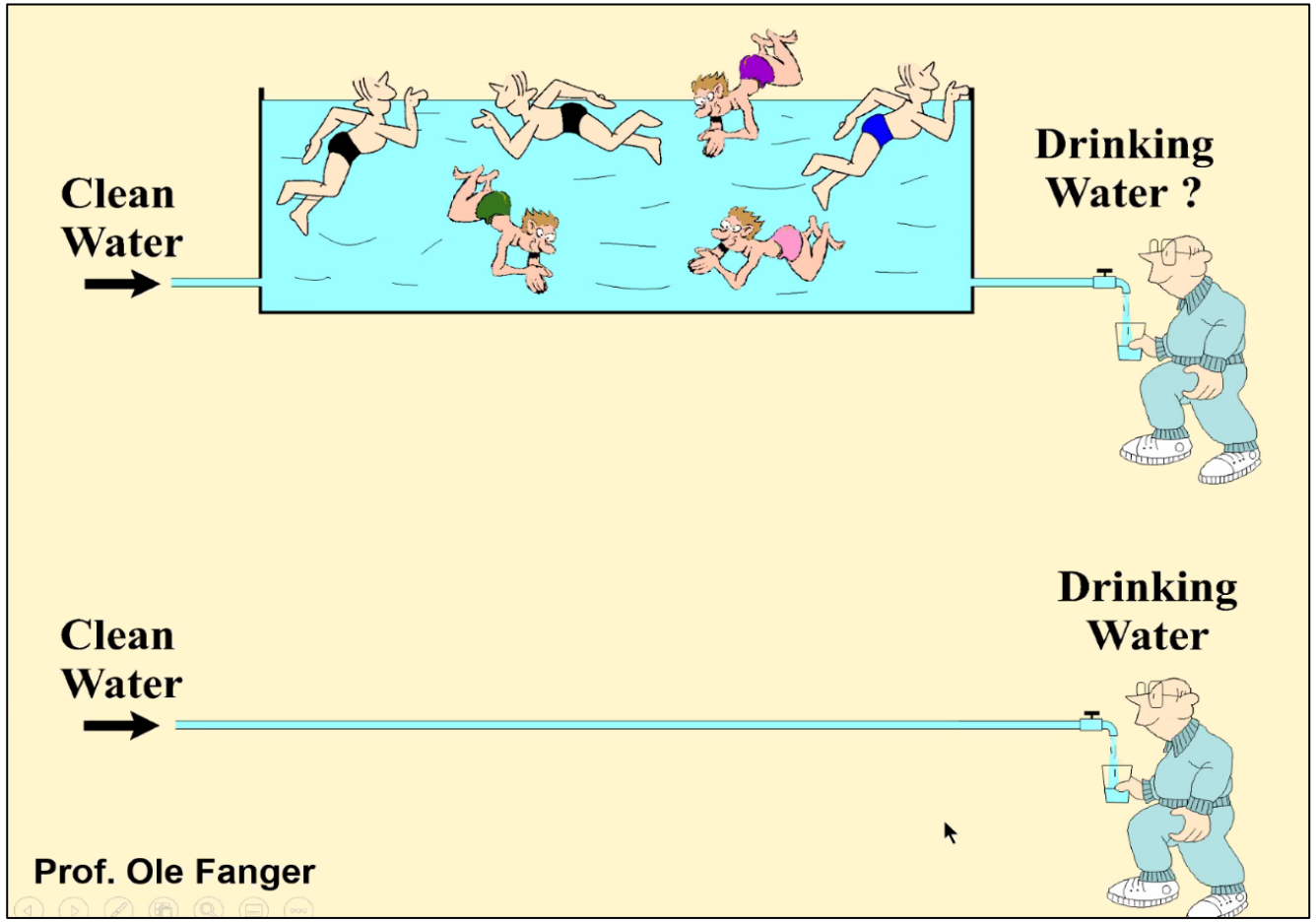
EXTERIOR
Ozono
Interior: purificadores de aire con ozono

Aerosoles biológicos

SCOVs

4

No podemos controlar el aire que respiramos en los espacios públicos



Si no nos beberíamos el agua de la primera figura ¿por qué nos conformamos con respirar el aire exhalado por otros y el aire cargado de contaminantes de un espacio mal ventilado?

FACTORES QUE AFECTAN A LA CALIDAD DEL AIRE INTERIOR

PARTICULAS PM_{10} Y $PM_{2.5}$

Limite anual

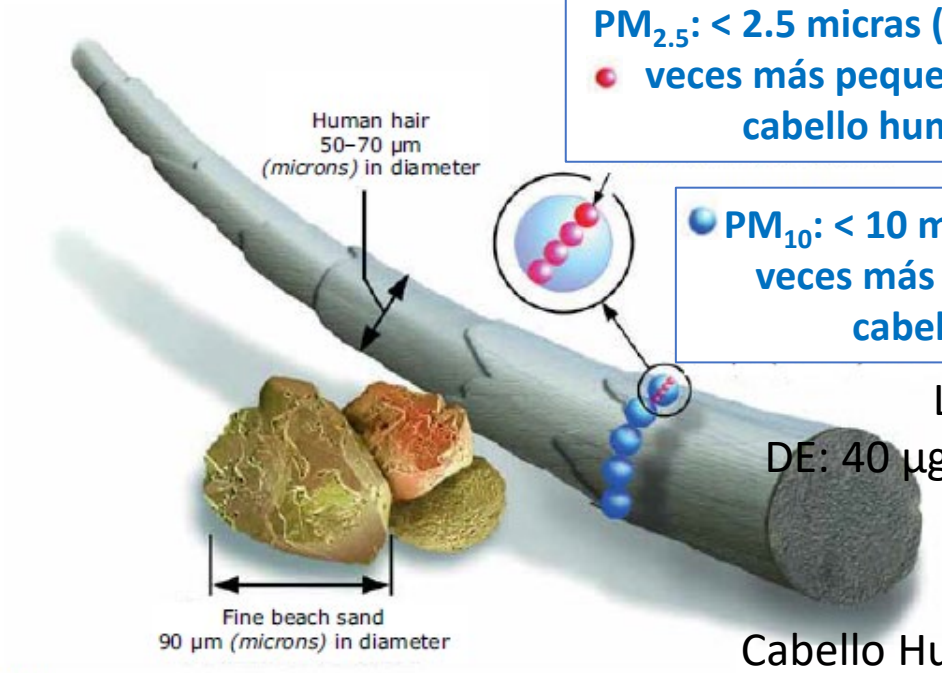
UE: 25 µg/m³ /OMS 5 µg/m³

$PM_{2.5}$: < 2.5 micras (µm), unas 20 veces más pequeña que un cabello humano

PM_{10}: < 10 micras (µm), unas 5 veces más pequeña que un cabello humano

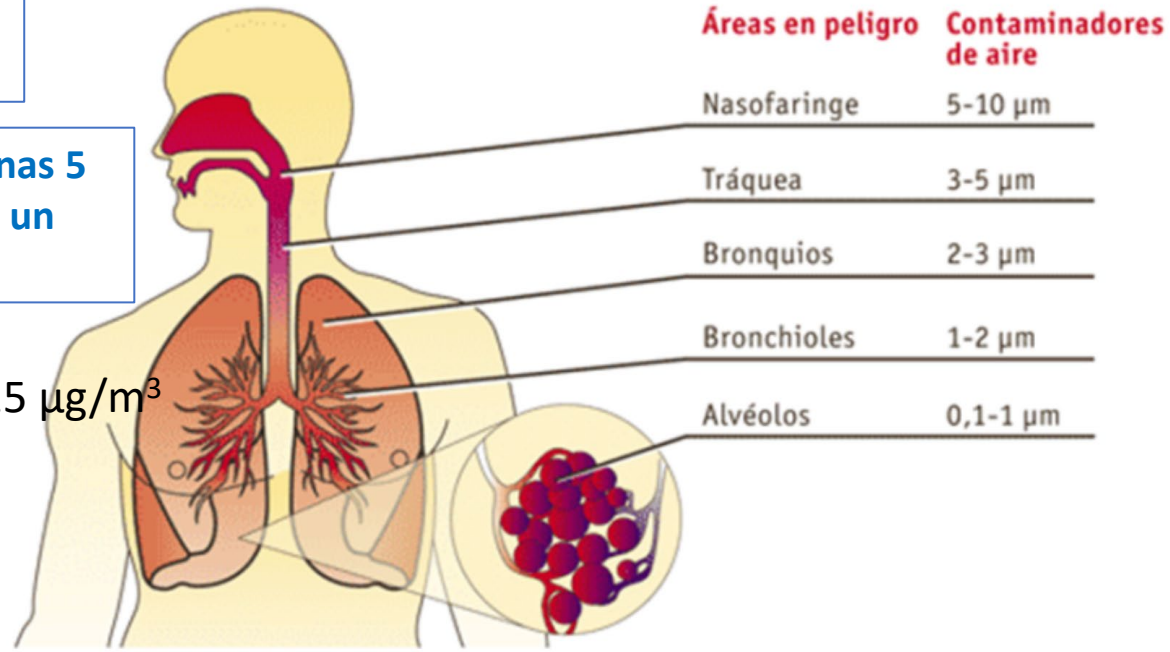
Limite anual

DE: 40 µg/m³ /OMS 15 µg/m³



Cabello Humano

Source: EPA, 2010.



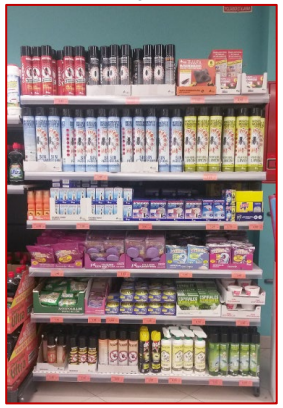
OMS: Los riesgos para la salud asociados al material particulado igual o menor a 10 y 2.5 micras (µm) son de particular relevancia para la salud pública . Pueden entrar en el torrente sanguíneo y afectar al sistema respiratorio, cardiovascular y otros órganos.

En 2013 fueron clasificadas como cancerígenas (cancer de pulmón) por la Agencia Internacional de Investigaciones sobre el cáncer (IARC) de la OMS

CONTAMINACIÓN DEL AIRE INTERIOR

COMPUESTOS ORGÁNICOS VOLÁTILES (COVs)

(Principales contaminantes del aire interior)



CONTAMINACIÓN DEL AIRE INTERIOR

COMPUESTOS ORGÁNICOS VOLÁTILES (COVs)

(Principales contaminantes del aire interior)

Indoor Air. 2021;31:2033–2048.

Emissions of soot, PAHs, ultrafine particles, NO_x, and other health relevant compounds from stressed burning of candles in indoor air

Christina Andersen[1] | Yuliya Omelekhina[1] | Berit Brøndum Rasmussen[2] | Mette Nygaard Bennekov[2] | Søren Nielsen Skov[3,4] | Morten Køcks[3] | Kai Wang[2,5] | Bo Strandberg[6] | Fredrik Mattsson[1] | Merete Bilde[2] | Marianne Glasius[2] | Joakim Pagels[1] | Aneta Wierzbicka[1]

VELAS AROMÁTICAS

Quemar una vela durante 1 h puede producir suficiente NO_2 como para aumentar la concentración interior próxima al limite establecido por la OMS (200 µg/m^3)

También genera:

Partículas (PM) y UFP

PAHs

COVs

Problemas respiratorios, cardiovasculares y cognitivos

CONTAMINACIÓN DEL AIRE INTERIOR

COMPUESTOS ORGÁNICOS VOLÁTILES (COVs)

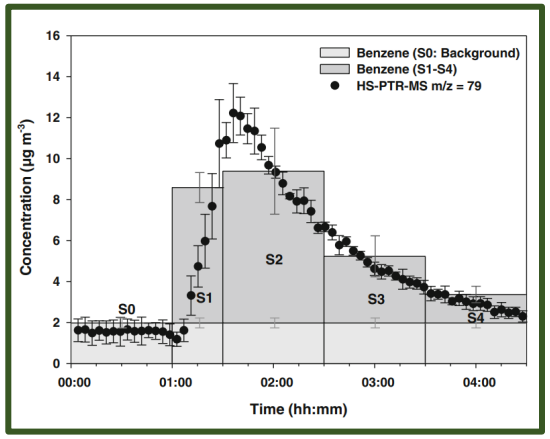
(Principales contaminantes del aire interior)

Environ Sci Pollut Res (2013) 20:4659–4670
DOI 10.1007/s11356-012-1394-y

RESEARCH ARTICLE

Emission characteristics of air pollutants from incense and candle burning in indoor atmospheres

A. Manoukian · E. Quivet · B. Temime-Roussel · M. Nicolas · F. Maupetit · H. Wortham



Compounds
Candle
Monoterpenes ($C_{10}H_{16}$)
Incense
Acenaphthene ($C_{12}H_{10}$)
Acetaldehyde (C_2H_4O)
Acetone (C_3H_6O)
Acrylonitrile (C_3H_3N)
Benzaldehyde (C_7H_6O)
Benzene (C_6H_6)
Biphenyl ($C_{12}H_{10}$)
Butadiene (C_4H_6)
Butyraldehyde (C_4H_8O)
Ethanol (C_2H_6O)
Ethylbenzene (C_8H_{10})
Formaldehyde (CH_2O)
Furfural ($C_5H_4O_2$)
Furfuryl alcohol ($C_5H_6O_2$)
Hexaldehyde ($C_6H_{12}O$)
Isoprene (C_5H_8)
Linalool ($C_{10}H_{18}O$)
5-Methylfurfural ($C_6H_6O_2$)
Monoterpenes ($C_{10}H_{16}$)
Naphthalene ($C_{10}H_8$)
Pentanal ($C_5H_{10}O$)
Pentanone ($C_5H_{10}O$)
Propionaldehyde (C_3H_6O)
Styrene (C_8H_8)
Toluene (C_7H_8)
Xylene $(C_6H_4CH_3)_2$

Incense sticks emitted carcinogenic substances (i.e., benzene and formaldehyde) attaining the concentration levels close to the WHO guideline exposure threshold values, i.e., 17 µgm^{-3} (concentration associated with an excess lifetime risk of 1/10,000) and 100 µgm−3 (30-min average concentration), respectively (WHO 2010).

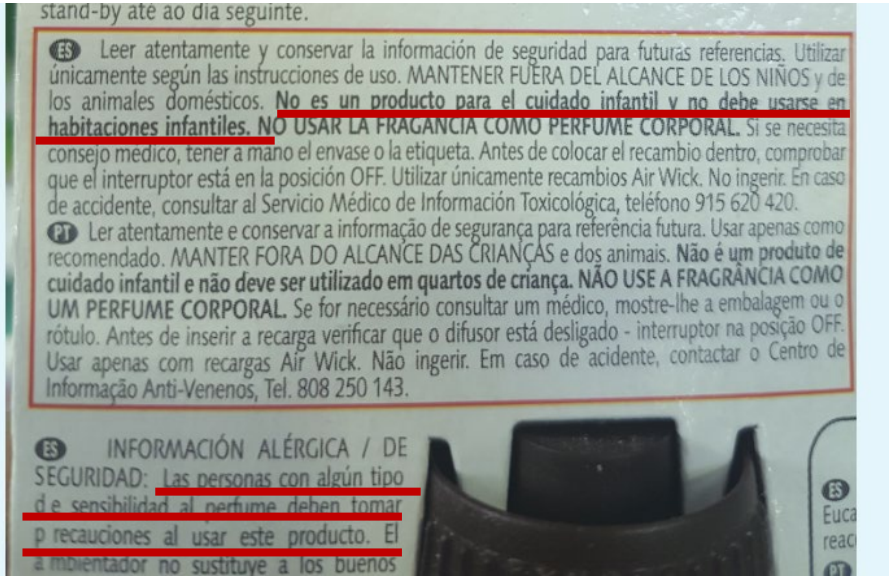
CONTAMINACIÓN DEL AIRE INTERIOR

COMPUESTOS ORGÁNICOS VOLÁTILES (COVs)

(Principales contaminantes del aire interior)

AMBIENTADORES

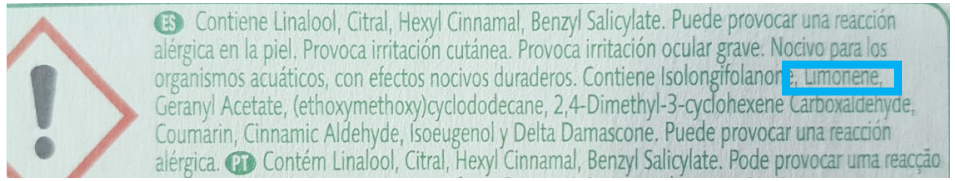
¿LEEMOS LA ETIQUETA?


stand-by até ao dia seguinte.

ES Leer atentamente y conservar la información de seguridad para futuras referencias. Utilizar únicamente según las instrucciones de uso. MANTENER FUERA DEL ALCANCE DE LOS NIÑOS y de los animales domésticos. No es un producto para el cuidado infantil y no debe usarse en habitaciones infantiles. NO USAR LA FRAGANCIA COMO PERFUME CORPORAL. Si se necesita consejo médico, tener a mano el envase o la etiqueta. Antes de colocar el recambio dentro, comprobar que el interruptor está en la posición OFF. Utilizar únicamente recambios Air Wick. No ingerir. En caso de accidente, consultar al Servicio Médico de Información Toxicológica, teléfono 915 620 420.

PT Ler atentamente e conservar a informação de segurança para referência futura. Usar apenas como recomendado. MANTER FORA DO ALCANCE DAS CRIANÇAS e dos animais. **Não é um produto de cuidado infantil e não deve ser utilizado em quartos de criança. NÃO USE A FRAGRÂNCIA COMO UM PERFUME CORPORAL.** Se for necessário consultar um médico, mostre-lhe a embalagem ou o rótulo. Antes de inserir a recarga verificar que o difusor está desligado - interruptor na posição OFF. Usar apenas com recargas Air Wick. Não ingerir. Em caso de acidente, contactar o Centro de Informação Anti-Venenos, Tel. 808 250 143.

ES INFORMACIÓN ALÉRGICA / DE SEGURIDAD: Las personas con algún tipo de sensibilidad al perfume deben tomar precauciones al usar este producto. El ambientador no sustituye a los buenos


ES Contiene Linalool, Citral, Hexyl Cinnamal, Benzyl Salicylate. Puede provocar una reacción alérgica en la piel. Provoca irritación cutánea. Provoca irritación ocular grave. Nocivo para los organismos acuáticos, con efectos nocivos duraderos. Contiene Isolongifolanone, Limonene, Geranyl Acetate, (ethoxymethoxy)cyclododecane, 2,4-Dimethyl-3-cyclohexene Carboxaldehyde, Coumarin, Cinnamic Aldehyde, Isoeugenol y Delta Damascone. Puede provocar una reacción alérgica. PT Contém Linalool, Citral, Hexyl Cinnamal, Benzyl Salicylate. Pode provocar uma reacção

Problemas de salud: Irritación sensorial, síntomas respiratorios y disfunción pulmonar

Ingredientes ambientador + Ozono → Formaldehido + aerosoles (SOA) + particulas ultrafinas

(ej. Limoneno)

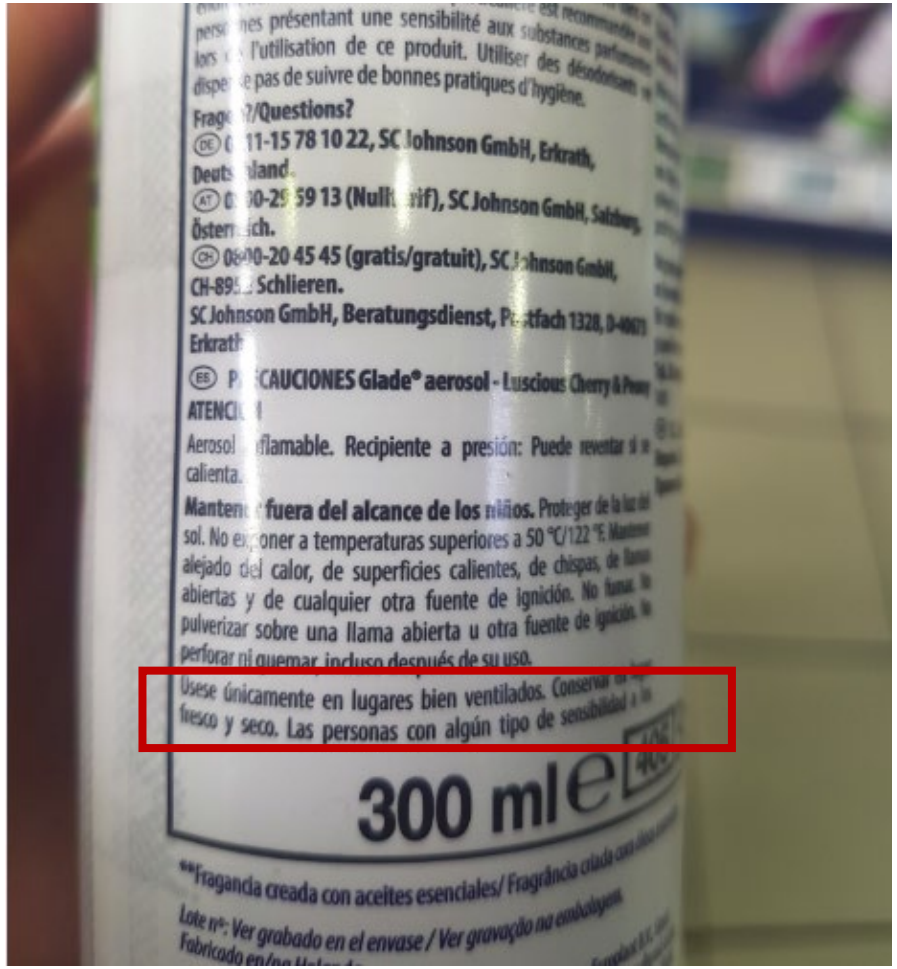
Problemas respiratorios y cardiovasculares

CONTAMINACIÓN DEL AIRE INTERIOR

COMPUESTOS ORGÁNICOS VOLÁTILES (COVs)

(Principales contaminantes del aire interior)

AMBIENTADORES

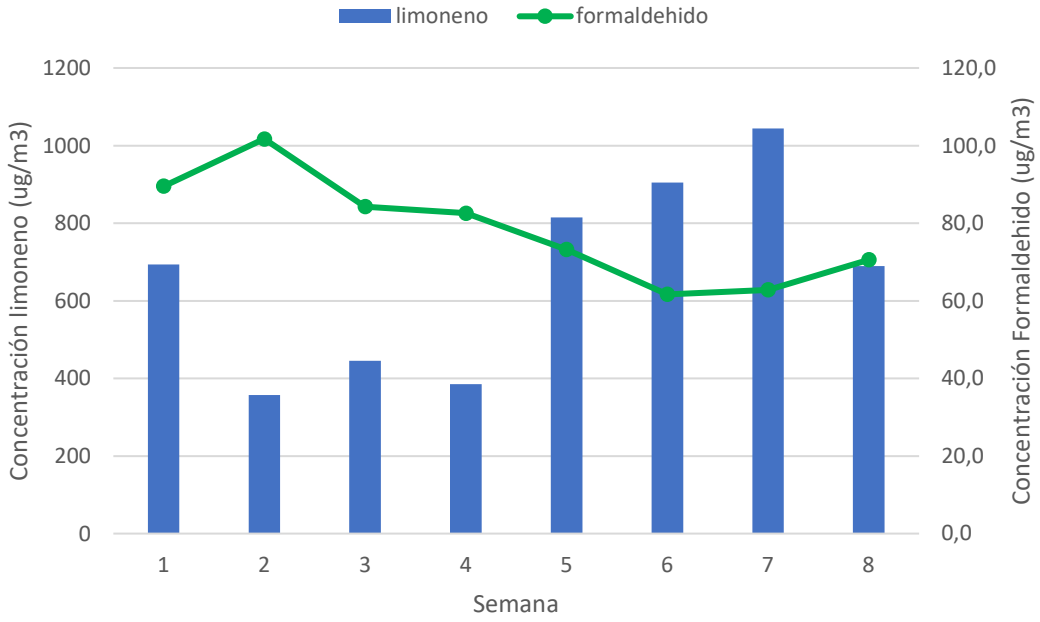


Los productos con fragancias se han asociado con una variedad de efectos adversos para la salud:
migrañas
ataques de asma
dificultades respiratorias
problemas neurológicos
síntomas de las mucosas
y dermatitis de contacto.
(Steinemann, 2016)

CONTAMINACIÓN DEL AIRE INTERIOR

COMPUESTOS ORGÁNICOS VOLÁTILES (COVs)

Promedio limoneno = 667 μgm^{-3}



Correlación Pearson=- 0,829*

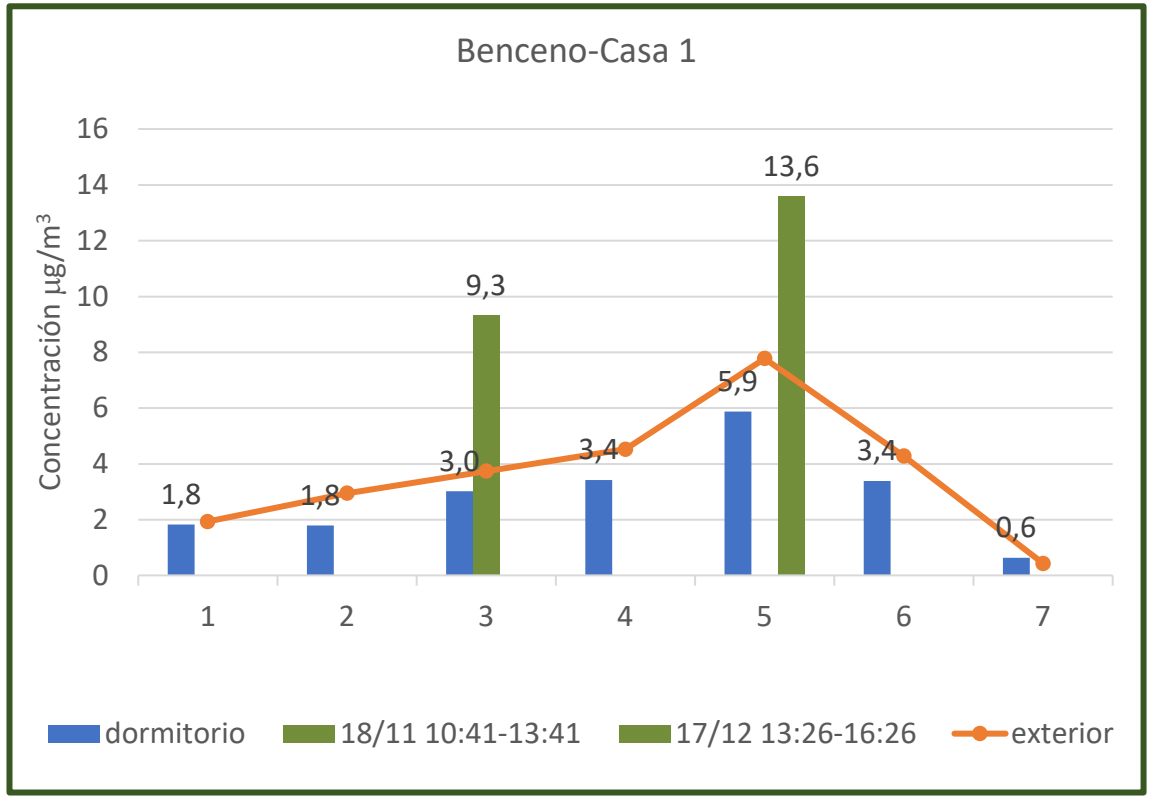
Está presente en productos de limpieza y cuidado personal, también está presente como fragancia en los ambientadores por lo que éste pudo haber sido su origen.

Guias Belga de calidad del aire: 450 μgm^{-3} (valor guía largo plazo)

Reacciones secundarias con formación de aerosoles

CONTAMINACIÓN DEL AIRE INTERIOR

COMPUESTOS ORGÁNICOS VOLÁTILES (COVs)

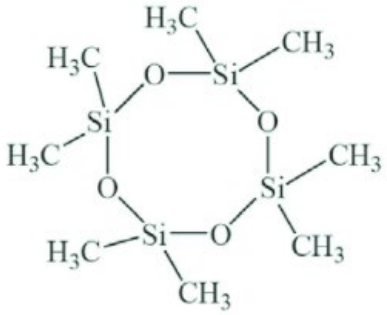


Benceno procedente del exterior

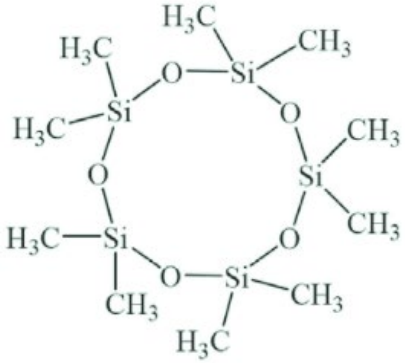
CONTAMINACIÓN DEL AIRE INTERIOR

COMPUESTOS ORGÁNICOS VOLÁTILES (COVs)

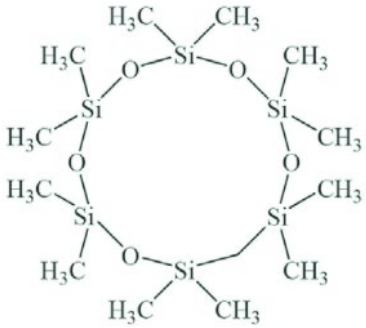
Se han identificado en todas los dormitorios siliconas cíclicas volátiles D4, D5 y D6.
Se han cuantificado con los captadores activos. La mayor concentración se obtiene para la D5 (30-132 μgm^{-3}). Se necesita una investigación más profunda para determinar el comportamiento y distribución de estas siliconas en ambientes interiores



D4: octametilciclotetrasiloxano



D5: decametilciclopentasiloxano



D6: dodecametilciclohexasiloxano

PARQUE CIENTÍFICO Y TECNOLÓGICO DE CASTILLA - LA MANCHA

ICCA INSTITUTO DE INVESTIGACIÓN EN COMBUSTIÓN Y CONTAMINACIÓN ATMOSFÉRICA

QUÍMICA Y CONTAMINACIÓN DEL AIRE INTERIOR

Environmental Science & Technology

Article

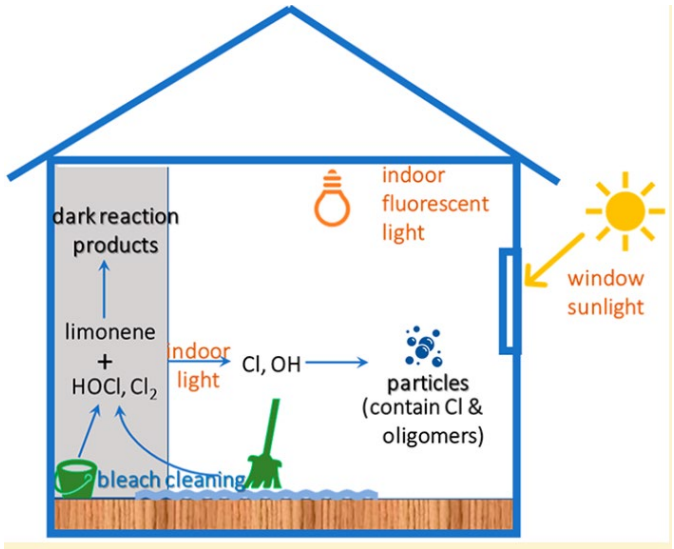
Cite This: *Environ. Sci. Technol.* 2019, 53, 11792−11800

pubs.acs.org/est

Indoor Illumination of Terpenes and Bleach Emissions Leads to Particle Formation and Growth

Chen Wang,*,† Douglas B. Collins,†,‡ and Jonathan P.D. Abbatt†

El uso de lejía genera grandes cantidades de compuestos clorados



Environmental Science Processes & Impacts

ROYAL SOCIETY OF CHEMISTRY

EDITORIAL

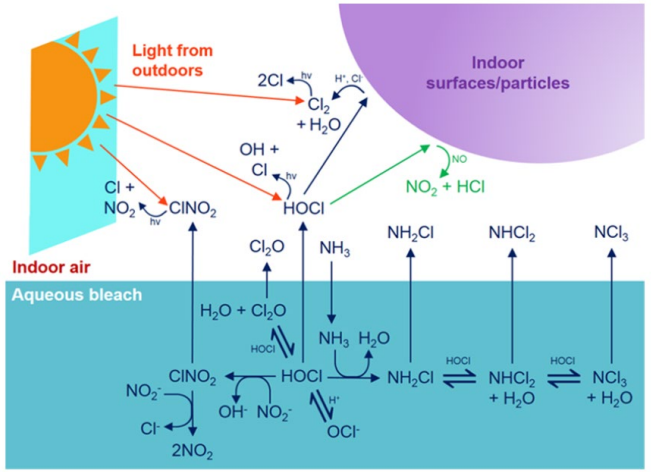
View Article Online
View Journal | View Issue

Check for updates

Cite this: *Environ. Sci.: Processes Impacts*, 2019, **21**, 1227

Indoor air: sources, chemistry and health effects

Delphine K. Farmer *[a] and Marina E. Vance [b]



Mattila et al., 2020
https://dx.doi.org/10.1021/acs.est.9b05767
Environ. Sci. Technol. 2020, 54, 1730−1739

PROYECTO HOMEChem (USA)

- Campaña de aire interior donde los investigadores simulares a diario las distintas actividades típicas del hogar como limpiar, cocinar, ventilar etc. (Arata et al., 2021)
- El objetivo era conocer como las actividades cotidianas influyen en las emisiones, las transformaciones químicas y en la eliminación de gases traza y partículas en el aire interior.
- Se observó que durante **los periodos de no ocupación** de la vivienda la concentración de muchos COVs era superior a la del exterior, relacionándose con las emisiones procedentes de los **materiales empleados en la vivienda**, que son fuentes potenciales de estos compuestos.
- Los experimentos realizados **durante la ocupación** de las viviendas mostraron la emisión de grandes cantidades de **siloxanos** (siliconas volátiles) empleados en los productos de cuidado personal.

The UTest House in Austin, Texas. Photo: Callie Richmond

- Finalmente, a partir de los resultados, se simularon las emisiones de COVs durante un período hipotético de 24 horas, lo que demostró que las emisiones de la casa y su contenido representaban casi la mitad de las emisiones totales de COVs en interiores.

COCINAR Y SU RELACIÓN CON LAS PARTICULAS

Environmental Science Processes & Impacts

PAPER

View Article Online
View Journal | View Issue

Check for updates

Cite this: *Environ. Sci.: Processes Impacts*, 2019, **21**, 1280

Overview of HOMEChem: House Observations of Microbial and Environmental Chemistry†

D. K. Farmer,[a] M. E. Vance,[b] J. P. D. Abbatt,[c] A. Abeleira,[a] M. R. Alves,[d] C. Arata,[e] E. Boedicker,[a] S. Bourne,[f] F. Cardoso-Saldaña,[f] R. Corsi,[gq] P. F. DeCarlo,[hi] A. H. Goldstein,[ej] V. H. Grassian,[d] L. Hildebrandt Ruiz,[f] J. L. Jimenez,[k] T. F. Kahan,[lm] E. F. Katz,[h] J. M. Mattila,[a] W. W. Nazaroff,[j] A. Novoselac,[q] R. E. O'Brien,[n] V. W. Or,[d] S. Patel,[t] M. Wade,[f] C. Wang,[c] S. Zhou[t] and

POLLUTANT	AVERAGING TIME	WHO 2021 AIR QUALITY GUIDELINE
$PM_{2.5}$ (μg/m^3)	Annual	5
	24-hour	15
PM_{10} (μg/m^3)	Annual	15
	24-hour	45

Ventanas y puertas cerradas

Cocinar es la principal fuente de partículas submicrométricas

La mayor concentración de partículas ocurre durante el desayuno y los sofritos de verduras.

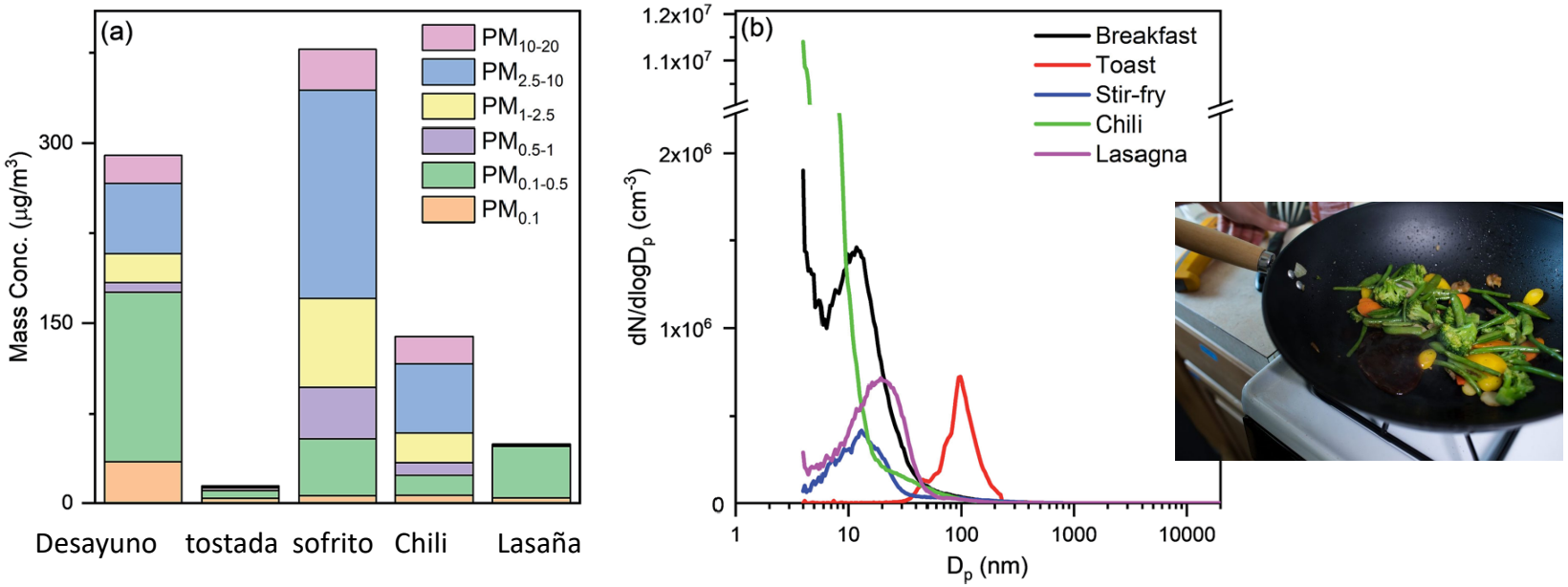
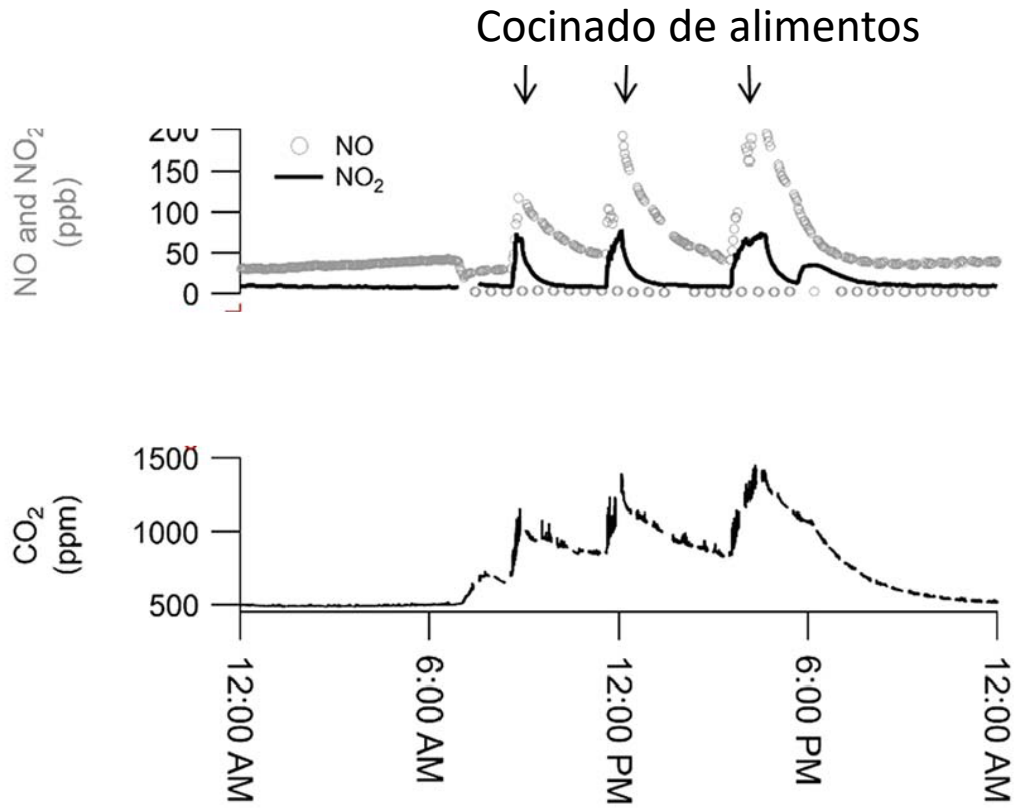
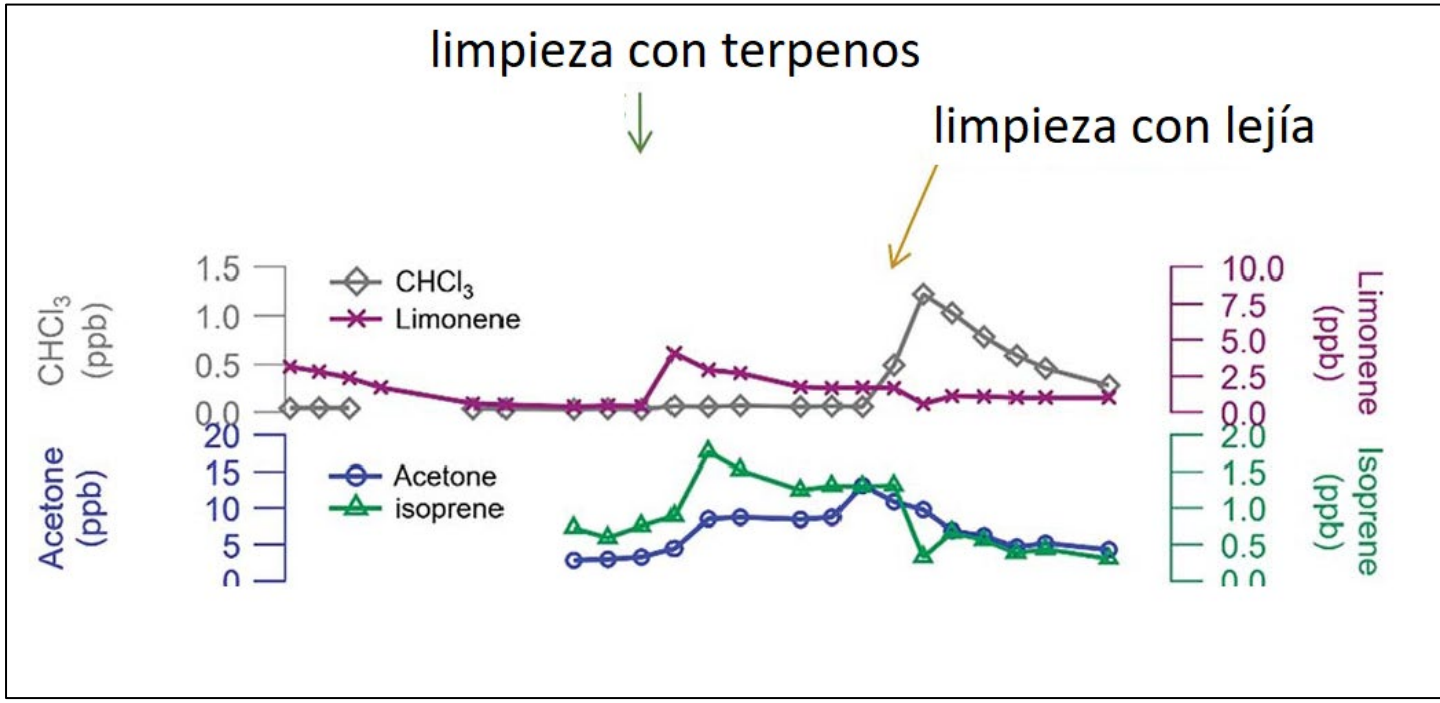


Fig. 6 (a) The highest mass concentrations by size ($PM_{0.1}$, $PM_{0.5}$, PM_1, $PM_{2.5}$, PM_{10}, and PM_{20}) during the preparation of each meal. (b) Particle number size distributions (electrical mobility size: 4 nm–532 nm; aerodynamic size: 542 nm–19.8 μm) corresponding to the highest PM mass concentrations recorded during different types of meals cooked. Mass calculations from size distribution measurements assume a constant aerosol density of 1 g cm^{-3}.

COCINAR Y LIMPIAR





EFECTOS EN LA SALUD

La contaminación atmosférica de los ambientes interiores puede producir un riesgo importante sobre la salud de los ocupantes.

Gran cantidad de tipos de contaminantes y sus posibles efectos combinados.

Efectos a corto plazo

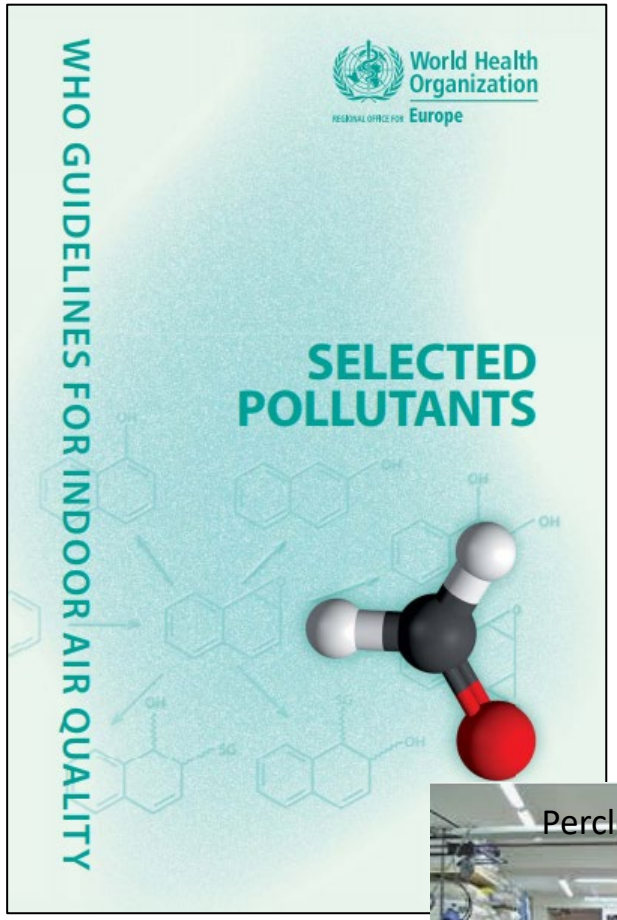
Efectos a largo plazo

Irritación de ojos, nariz y garganta, dolores de cabeza, mareos, fatiga y síntomas de asma agravados o empeorados entre los asmáticos

Exposición crónica: Pueden incluir enfermedades respiratorias, enfermedades del corazón y cáncer.

CONTAMINACIÓN DEL AIRE INTERIOR Y SALUD

CONTAMINANTES DEL AIRE INTERIOR



Compuesto	Valores limite (OMS)
Benceno	No existe un nivel umbral por debajo del cual sea seguro para la salud
CO	15 min - 100 mg m^{-3} 1 hora - 35 mg m^{-3} 8 horas - 10 mg m^{-3} 24 horas - 7 mg m^{-3}
Formaldehido	30 min promedio- 100 µg m^{-3}
NO_2	1 hora - 200 µg m^{-3} anual- 40 µg m^{-3}
Hidrocarburos aromáticos policiclicos-Benzo(a)pireno	No existe un nivel umbral por debajo del cual sea seguro para la salud. Todas las exposiciones son relevantes para la salud
Compuestos halogenados	Tricloroetileno: 2,3 µg m^{-3} da $1/10^6$ Tetracloroetileno. anual-250 µg m^{-3}
Material particulado (PM10 y PM2.5)	PM10 anual- 20 µg m^{-3} PM2.5 anual – 10 µg m^{-3}

HEALH CANADA
ANSES-FRANCIA
PHE-REINO UNIDO

EFECTOS EN LA SALUD

https://link.springer.com/article/10.1007/s42452-019-0405-8

Table 3 Top ten diseases and risks associated with household air pollution

Disease/illness	Causative pollutants	Number of studies including meta-analysis	Pooled Statistic		References
			Odds ratio	Limits of CI (95%)	
Respiratory illness	Benzene, 1,3 butadiene, CO, formaldehyde, NO_x, polycyclic aromatic hydrocarbons (PAHs), $PM_{2.5}$, PM_{10}, SO_2	30 (10 case–control studies; 19 cross-sectional studies, 1 review)	2.13	1.30–3.49	[13, 70–72]
Asthma	Animal dander, aldehydes, CO, dust, ETS, mono-aromatics, molds, NO_2, O_3, phenols, PM, pollen	21 (4 case–control studies; 14 cross-sectional studies; 1 longitudinal study; 2 reviews)	1.81	0.79–3.27	[13, 72–77]
Pneumonia	Asbestos, benzene, CO, formaldehyde, NO_2, PAHs, $PM_{2.5}$, PM_{10}, SO_2	27 (18 case–control studies; 3 cross-sectional studies; 5 cohort studies; 1 randomized control trial study)	2.50	1.51–4.3	[78–80]
Tuberculosis	Bacterial microorganism, kerosene, PM, pollens, tobacco smoke	16 (13 case–control studies; 3 cross-sectional studies)	1.44	0.82–2.62	[14, 81–83]
Lung function reduction	Asbestos, CO, CO_2, NO_x, O_3, radon, SO_2, tobacco smoke, VOCs	26 (9 case–control studies; 17 cross-sectional studies)	1.92	0.92–4.83	[13, 84]
Cancer	Asbestos, benzene, 1,3 butadiene, CO, NO_x, O_3, $PM_{2.5}$, PM_{10}, radon and VOCs	36 (35 case–control studies; 1 cohort study)	2.32	1.46–3.97	[30, 85–88]
Cardiovascular diseases	CO, CO_2, NO_x, O_3, $PM_{2.5}$, PM_{10}, radon, SO_2, tobacco smoke, VOCs	23 (13 case–control studies; 1 cross-sectional study; 9 cohort studies)	2.25	1.32–5.15	[89–93]
Eye diseases	Asbestos, CO, CO_2, kerosene, NO_x, O_3, SO_2, VOCs	19 (8 case–control studies; 10 cross-sectional studies; 1 randomized control trial study)	2.03	1.07–5.10	[94]
Pregnancy complications	CO, CO_2, ETS, NO_x, O_3, PM, Radon, SO_2, VOCs	5 (4 cross-sectional studies; 1 cohort study)	1.65	1.27–2.22	[95–99]
Sick building syndrome	Allergens, asbestos, bacteria, CO, CO_2, fungal spores, NO_x, O_3, PM, SO_2, VOCs	2 (1 longitudinal study; 1 cross-sectional study)	1.32	0.95–2.27	[100, 101]

Review Paper

Impact of household air pollution on human health: source identification and systematic management approach

Fahad Ahmed[1] · Sahadat Hossain[2] · Shakhaoat Hossain[2] · Abu Naieum Muhammad Fakhruddin[1] · Abu Tareq Mohammad Abdullah[3] · Muhammed Alamgir Zaman Chowdhury[4] · Siew Hua Gan[5]

© Springer Nature Switzerland AG 2019

Altas concentraciones de COVs en las casas están asociadas con un aumento en la prevalencia de asma y rinitis en adultos.

Los problemas de salud que resultan de la mala calidad del aire interior no son fácilmente reconocidos y pueden afectar a la salud del paciente años después del inicio de la exposición (Seguel et al., 2017 American Journal of Lifestyle Medicine)

PARQUE CIENTÍFICO Y TECNOLÓGICO DE CASTILLA - LA MANCHA

ICCA INSTITUTO DE INVESTIGACIÓN EN COMBUSTIÓN Y CONTAMINACIÓN ATMOSFÉRICA

EFECTOS RESPIRATORIOS

The Use of Household Cleaning Sprays and Adult Asthma

An International Longitudinal Study

Zock JP, Plana E, Jarvis D, et al. The use of household cleaning sprays and adult asthma. *Am J Respir Crit Care Med.* 2007;176:735-741.

TABLE 2. ASSOCIATIONS BETWEEN THE USE OF CLEANING PRODUCTS AT LEAST WEEKLY AND THE INCIDENCE OF ASTHMA (n = 3,503)

Cleaning Product	Use ≥ 1 d/wk Among All Participants (%)	Current Asthma* RR (95% CI)	Current Wheeze† RR (95% CI)	Physician-diagnosed Asthma‡ HR (95% CI)
Washing powders	78.6	1.10 (0.75–1.63)	1.28 (0.91–1.81)	0.82 (0.43–1.54)
Liquid multiuse cleaning products	83.1	0.94 (0.64–1.38)	0.97 (0.70–1.35)	0.98 (0.52–1.86)
Polishes, waxes	8.7	1.12 (0.71–1.76)	1.19 (0.77–1.85)	1.42 (0.68–2.97)
Bleach	28.0	1.22 (0.83–1.80)	1.30 (0.90–1.87)	1.10 (0.56–2.17)
Ammonia	7.2	1.40 (0.87–2.23)	1.31 (0.81–2.13)	0.92 (0.33–2.59)
Decalcifiers, acids	11.1	1.06 (0.70–1.61)	1.18 (0.77–1.80)	0.25 (0.06–1.04)
Solvents, stain removers	5.5	1.54 (0.94–2.53)	2.00 (1.30–3.07)	0.48 (0.12–1.97)
Furniture sprays	11.6	1.49 (0.99–2.23)	1.46 (0.98–2.19)	2.46 (1.26–4.80)
Glass-cleaning sprays	22.1	1.35 (0.98–1.85)	1.49 (1.12–2.00)	1.43 (0.84–2.44)
Sprays for carpets, rugs, curtains	1.3	1.24 (0.47–3.21)	0.80 (0.26–2.41)	0.80 (0.11–5.93)
Sprays for mopping the floor§	6.1	1.05 (0.59–1.85)	1.03 (0.59–1.79)	0.93 (0.30–2.85)
Oven sprays	2.0	0.87 (0.33–2.28)	1.24 (0.57–2.69)	0.63 (0.09–4.64)
Ironing sprays	3.0	1.66 (0.92–3.00)	1.05 (0.48–2.30)	1.51 (0.46–4.96)
Air-refreshing sprays	16.2	1.71 (1.22–2.39)	1.36 (0.98–1.88)	1.46 (0.78–2.70)
Any spray	42.1	1.49 (1.12–1.99)	1.39 (1.06–1.80)	1.28 (0.78–2.09)
Any perfumed or scented product	67.8	1.09 (0.78–1.50)	1.11 (0.83–1.49)	1.29 (0.74–2.26)

Definition of abbreviations: CI = confidence interval; HR = hazard ratio; RR = relative risk.

RRs*† or HRs‡ with 95% CIs from log-binomial*† or Cox proportional hazards‡ regression models, adjusted for sex, age, smoking status, cleaning job, and study center. The reference category consisted of participants that used the cleaning product under study never or less than once a week. Each association was derived from a separate regression model.

* Attack of asthma and/or nocturnal attack of shortness of breath in the last 12 months and/or current asthma medication (n = 3,483).

† Wheezing or whistling in the chest when not having a cold in the last 12 months (n = 3,480).

‡ Diagnosis of asthma with recorded year of onset (n = 3,446).

- 10 Países Europeos
- 3503 personas que limpiaron sus casas y que no tenian asma fueron seguidas durante 9 años.
- Los resultados mostraron que el 42 % de los participantes, que limpiaron al menos una vez a la semana, experimentaron sintomas asmáticos o usaban medicación para el asma y las sibilancias.
- Los responsables: limpiacristales, ambientadores y limpiadores de muebles en spray.
- El uso de productos de limpieza en spray puede ser un factor importatne de Desarrollo de asma en adultos.

EFECTOS EN LA SALUD

Hu et al., 2019

Impact on lung function among children exposed to home new surface materials: The seven Northeastern Cities Study in China *Indoor Air*. 2019;1–10.

Contents lists available at ScienceDirect

International Journal of Hygiene and Environmental Health

journal homepage: www.elsevier.com/locate/ijheh

Household exposure to pesticides and risk of leukemia in children and adolescents: Updated systematic review and meta-analysis

Geneviève Van Maele-Fabry[a,*], Laurence Gamet-Payrastre[b], Dominique Lison[a]

Liu et al., 2018

Household renovation before and during pregnancy in relation to preterm birth and low birthweight in China *Indoor Air*. 2019;29:202–214.

Anne Steinemann[1,2]

Chemical sensitivity, asthma, and effects from fragranced consumer products: National Population Study in the United Kingdom

Air Quality, Atmosphere & Health (2019) 12:371–377

Paciência et al., 2018

Exposure to indoor endocrine-disrupting chemicals and childhood asthma and obesity *Allergy*. 2019;1–15.

Anne Steinemann[1,2,3]

Fragranced consumer products: exposures and effects from emissions Air Qual Atmos Health (2016) 9:861–866

Arch Bronconeumol. 2013;49(1):22–27

ARCHIVOS DE BRONCONEUMOLOGIA

www.archbronconeumol.org

Revisión

Contaminación del aire interior y su impacto en la patología respiratoria

Luis Carazo Fernández[a], Ramón Fernández Alvarez[b,*], Francisco Javier González-Barcala[c] y José Antonio Rodríguez Portal[d]

[a] Sección de Neumología, Complejo Asistencial Universitario de León, León, España
[b] Área de Gestión de Pulmón, Servicio de Neumología, Hospital Universitario Central de Asturias, Oviedo, España
[c] Servicio de Neumología, Hospital Clínico Universitario, Santiago de Compostela, La Coruña. España
[d] Unidad Médico-Quirúrgica de Enfermedades Respiratorias (UMQER), Servicio de Neumología, Hospital Universitario Virgen del Rocío, Sevilla, España

PARQUE CIENTÍFICO Y TECNOLÓGICO DE CASTILLA - LA MANCHA

ICCA INSTITUTO DE INVESTIGACIÓN EN COMBUSTIÓN Y CONTAMINACIÓN ATMOSFÉRICA

ESTUDIOS CONTAMINACIÓN DEL AIRE INTERIOR

International Journal of Hygiene and Environmental Health 218 (2015) 522–534

Contents lists available at ScienceDirect

International Journal of Hygiene and Environmental Health

journal homepage: www.elsevier.com/locate/ijheh

Levels and sources of volatile organic compounds including carbonyls in indoor air of homes of Puertollano, the most industrialized city in central Iberian Peninsula. Estimation of health risk

Florentina Villanueva[a,b,*], Araceli Tapia[a], Mariano Amo-Salas[c], Alberto Notario[d], Beatriz Cabañas[a], Ernesto Martínez[a]

[a] Atmospheric Pollution Laboratory, Research Institute for Combustion and Atmospheric Pollution, University of Castilla La Mancha, Camino de Moledores s/n, 13071 Ciudad Real, Spain
[b] Castilla La Mancha Science and Technology Park, Paseo de la Innovación 1, 02006 Albacete, Spain
[c] Department of Mathematics, Faculty of Medicine, University of Castilla La Mancha, Camino de Moledores s/n, 13071 Ciudad Real, Spain
[d] Physical Chemistry Department, Faculty of Chemical Science and Technologies, University of Castilla La Mancha, Avenida Camilo José Cela s/n, 13071 Ciudad Real, Spain

ARTICLE INFO

Article history:
Received 5 March 2015
Received in revised form 29 April 2015
Accepted 4 May 2015

Keywords:
Indoor air
Aldehydes
VOCs
Passive samplers
Industrial area Puertollano
Health risk

ABSTRACT

Twenty nine organic air pollutants including carbonyl compounds, alkanes, aromatic hydrocarbons and terpenes were measured in the indoor environment of different houses together with the corresponding outdoor measurements in Puertollano, the most industrialized city in central Iberian Peninsula. VOCs were sampled during 8 weeks using Radiello® passive samplers, and a questionnaire on potential VOCs sources was filled out by the occupants. The results show that formaldehyde and hexanal was the most abundant VOCs measured in indoor air, with a median concentration of 55.5 and 46.4 $\mu g\,m^{-3}$, respectively followed by butanal (29.1 $\mu g\,m^{-3}$), acetone (28.4 $\mu g\,m^{-3}$) and acetaldehyde (21.4 $\mu g\,m^{-3}$). After carbonyls, *n*-dodecane (13.1 $\mu g\,m^{-3}$) and terpenes (α-pinene, 13.4 $\mu g\,m^{-3}$ and limonene, 13.4 $\mu g\,m^{-3}$) were the compounds with higher median concentrations. The indoor/outdoor (I/O) ratios demonstrated that sources in the indoor environment are prevailing for most of the investigated VOCs especially for limonene, α-pinene, hexanal, formaldehyde, pentanal, acetaldehyde, *o*-xylene, *n*-dodecane and acetone with I/O ratio >6. Multiple linear regressions were applied to investigate the indoor VOC determinants and Spearman correlation coefficients were used to establish common sources between VOCs. Finally, the lifetime cancer risk associated to formaldehyde, acetaldehyde and benzene exposure was estimated and they varied from 7.8×10^{-5} to 4.1×10^{-4} for formaldehyde, from 8.6×10^{-6} to 3.5×10^{-5} for acetaldehyde and from 2.0×10^{-6} to 1.5×10^{-5} for benzene. For formaldehyde, the attributed risk in most sampled homes was two orders of magnitude higher than the one (10^{-6}) proposed as acceptable by risk management bodies.

© 2015 Elsevier GmbH. All rights reserved.

Introduction

Exposure to indoor chemical air pollutants has a great impact on our health (e.g. Billionnet et al., 2011) because citizens spend most of their time inside buildings. For most organic air pollutants, significant correlations have been found between indoor concentrations and personal exposure, although personal exposures are typically vastly different from outdoor air concentrations (Payne-Sturges et al., 2004; Sexton et al., 2004). Among the most important categories of chemicals that occur in the indoor air are volatile organic compounds, VOCs, (such as BTXs benzene, toluene and xylenes) and also carbonyls (mainly formaldehyde and acetaldehyde) derived from furnishing material, paints, varnishes, solvents or cleaning products (e.g. Clarisse et al., 2003; Zabiegala, 2006; Esteve-Turillas et al., 2007).

VOCs emission arising from natural or industry/vehicles, for example, contribute to formation of ozone and photochemical

* Corresponding author at: University of Castilla La Mancha, Atmospheric Pollution Laboratory, Research Institute for Combustion and Atmospheric Pollution, Camino de Moledores s/n, 13071 Ciudad Real, Spain. Tel.: +34 926295300.
E-mail addresses: Florentina.vgarcia@uclm.es, Florentina.VGarcia@gmail.com (F. Villanueva), Araceli.tapia@uclm.es (A. Tapia), mariano.amo@uclm.es (M. Amo-Salas), Alberto.notario@uclm.es (A. Notario), Beatriz.cabanas@uclm.es (B. Cabañas), Ernestom.ataz@uclm.es (E. Martínez).

http://dx.doi.org/10.1016/j.ijheh.2015.05.004
1438-4639/© 2015 Elsevier GmbH. All rights reserved.

Microchemical Journal 142 (2018) 117–125

Contents lists available at ScienceDirect

Microchemical Journal

journal homepage: www.elsevier.com/locate/microc

Application of gas chromatography coupled with tandem mass spectrometry for the assessment of PAH levels in non industrial indoor air

Florentina Villanueva[a,b,*], Gema Sevilla[c], Sonia Lara[a], Pilar Martín[d], Sagrario Salgado[d], José Albaladejo[d], Beatriz Cabañas[a]

[a] Universidad de Castilla La Mancha. Instituto de Investigación en Combustión y Contaminación Atmosférica. Camino de Moledores s/n, 13071 Ciudad Real, Spain
[b] Parque Científico y Tecnológico de Castilla La Mancha, Paseo de la Innovación 1, 02006 Albacete, Spain
[c] Centro Nacional del Hidrogeno, Calle Fernando el Santo, 13500 Puertollano, Spain
[d] Universidad de Castilla La Mancha, Departamento de Química Física, Facultad de Ciencias y Tecnologías Químicas, Avenida Camilo José Cela s/n, 13071 Ciudad Real, Spain

ABSTRACT

A gas chromatographic coupled to a triple quadrupole tandem mass spectrometric (GC–MS/MS) method was optimized in order to measure the levels of polycyclic aromatic hydrocarbons (PAHs) in different non industrial indoor environments using active (filter + XAD-2) and passive (polyurethane, PUF) samplers. Ultrasonic and soxhlet extractions were used for active and passive samplers, respectively. The precision and accuracy of the analytical methods used were tested by spiking PUF, filters and XAD-2 with different working standards containing all analyzed PAH compounds. The proposed methods were applied to the analysis of real samples collected in the urban area of Ciudad Real, Spain. Nineteen PAHs were investigated in homes and workplaces such as petrol station stores (PSS), an underground parking office and the office of a periodic technical inspection of vehicles (PTI). The range of individual concentrations of PAH collected with the active sampler was from non detected to 144 $ng\,m^{-3}$ at home, from < LOD to 595 $ng\,m^{-3}$ at PSS, from 0.08 to 492 $ng\,m^{-3}$ at parking office and from non detected to 93 $ng\,m^{-3}$ at PTI office. Passive samplers were only employed at homes and the concentration range of PAH was from non detected to 5.1 $ng\,m^{-3}$. Naphthalene was the most abundant PAH in all samples using active samplers while phenanthrene was the most abundant at homes using passive samplers. Total concentrations of measured PAH (ΣPAH) were as follow: 283 $ng\,m^{-3}$ (home), 217–911 $ng\,m^{-3}$ (PSS), 732 $ng\,m^{-3}$ (parking office) and 216 $ng\,m^{-3}$ (PTI office). Three components were extracted from the application of PCA to the petrol stations stores accounting for 97.2% of the total variance.

A procedure to estimate the measurement uncertainty of PAH collected with active samplers has also been developed as it is an important issue in order to achieve accurate measurement results. The relative uncertainties were found to be in the range of 16–45% except for Acenaphthene whose uncertainty was around 54%.

1. Introduction

Polycyclic aromatic hydrocarbons (PAHs) are considered as toxic persistent substances and are ubiquitous environmental pollutants with carcinogenic and a number of other effects on human health [1]. Therefore, PAHs are generally included in monitoring programs and are classified by the US Environmental Protection Agency [2] and the European Community as priority pollutants [3]. In the outdoor environment, these pollutants are usually released from combustion sources such as coal burning power plants, diesel- and gasoline-powered vehicles, home heating, and waste treatment [4,5]. In the indoor air cooking, tobacco smoke, wood burning as well as the penetration of outdoor particulate and vapor phase PAHs into buildings have been recognized as major contributors to the indoor PAH air pollution [6]. An important aspect of air quality management is identification of indoor PAH sources. Research in indoor air quality is important since people spend up to 90% of their time in confined environments [1], therefore indoor PAH concentration and their distribution must be investigated in order to reliable assess the level of human exposure.

The application of a triple quadrupole tandem mass spectrometer (MS/MS) with selected reaction monitoring (SRM) mode or multiple reaction monitoring (MRM) mode is more specific than a simple MS

* Corresponding author.
E-mail addresses: Florentina.vgarcia@uclm.es (F. Villanueva), gema.sevilla@cnh2.es (G. Sevilla), Sonia.laragomez@uclm.es (S. Lara), Mariapilar.martin@uclm.es (P. Martín), sagrario.salgado@uclm.es (S. Salgado), Jose.albaladejo@uclm.es (J. Albaladejo), Beatriz.cabanas@uclm.es (B. Cabañas).

https://doi.org/10.1016/j.microc.2018.06.021
Received 3 May 2018; Received in revised form 11 June 2018; Accepted 12 June 2018
Available online 18 June 2018
0026-265X/ © 2018 Elsevier B.V. All rights reserved.

Chemosphere 288 (2022) 132429

Contents lists available at ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

Formaldehyde, acrolein and other carbonyls in dwellings of university students. Levels and source characterization

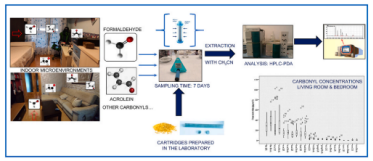
Florentina Villanueva[a,b,*], Sonia Lara[a], Alberto Notario[a,c], Mariano Amo-Salas[d], Beatriz Cabañas[a,c]

[a] Universidad de Castilla La Mancha, Instituto de Investigación en Combustión y Contaminación Atmosférica, Camino de Moledores S/n, 13071, Ciudad Real, Spain
[b] Parque Científico y Tecnológico de Castilla La Mancha, Paseo de La Innovación 1, 02006, Albacete, Spain
[c] Universidad de Castilla La Mancha, Departamento de Química Física, Facultad de Ciencias y Tecnologías Químicas, Avenida Camilo José Cela S/n, 13071, Ciudad Real, Spain
[d] Universidad de Castilla La Mancha, Departamento de Matemáticas, Facultad de Medicina, Camino de Moledores S/n, 13071, Ciudad Real, Spain

HIGHLIGHTS

- Radiello ® passive samplers refilled in the laboratory can be considered to measure carbonyl compounds in indoor air.
- The median concentration of formaldehyde, benzaldehyde, valeraldehyde and hexaldehyde was significantly higher in the bedrooms.
- The median concentration levels in bedrooms ($\mu g\,m^{-3}$) were 34.2 for formaldehyde, 23.1 for acetone and 15.8 for acetaldehyde.
- Indoor sources in university student flats played a decisive role in the concentrations of all measured carbonyls.
- All the carbonyls levels are below recommended indoor air quality guidelines except acrolein.

GRAPHICAL ABSTRACT



ARTICLE INFO

Handling Editor: R Ebinghaus

Keywords:
Indoor air
Formaldehyde
Carbonyls
Passive samplers
PCA
Source identification

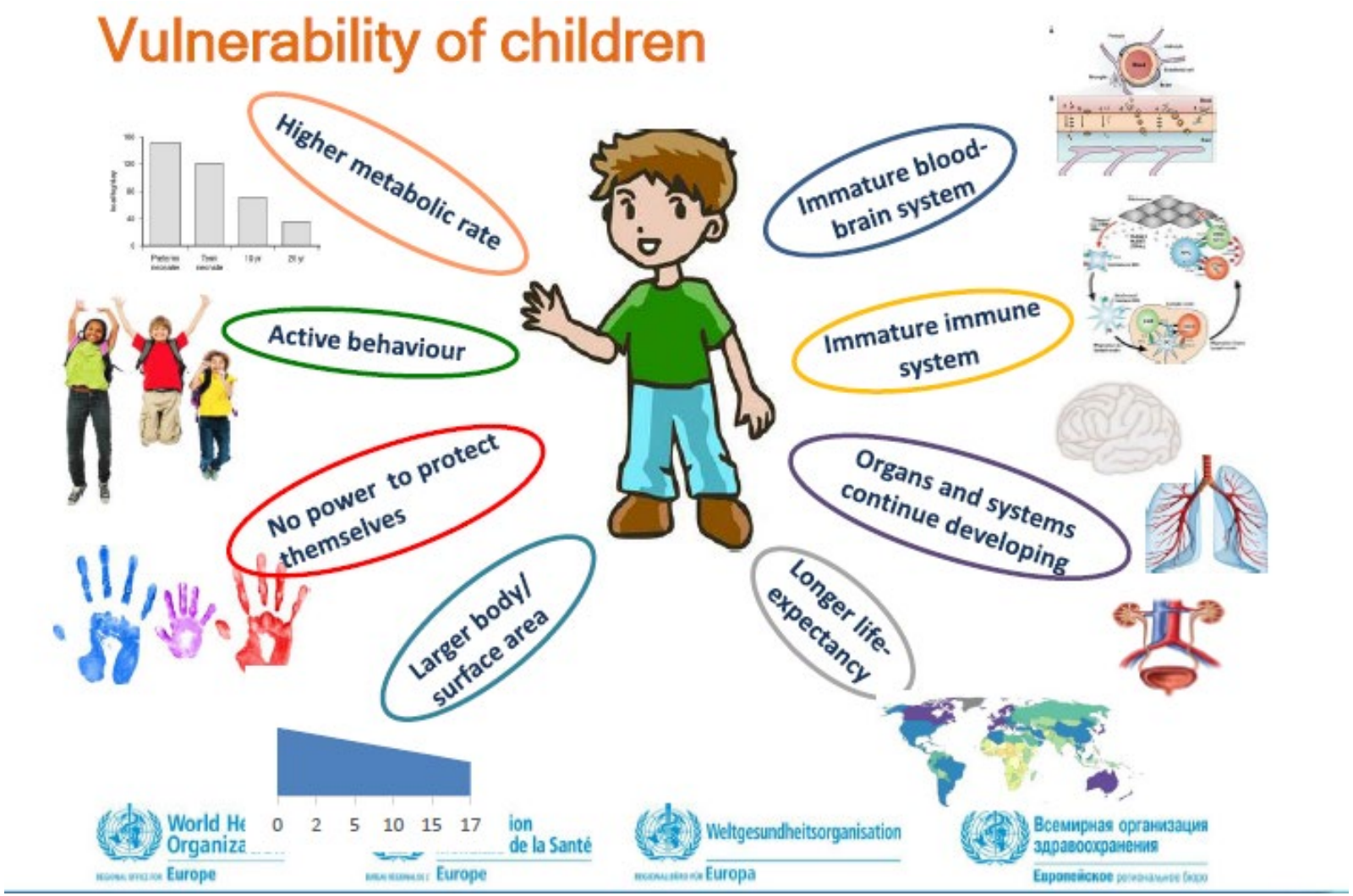
ABSTRACT

Fifteen carbonyl compounds were investigated in the living rooms and bedrooms of 25 university student flats in the urban area of Ciudad Real (Central Southern Spain) in wintertime. Carbonyls were sampled using Radiello ® passive samplers refilled in the laboratory according to the method described in ISO 16000-3 Standard. The most abundant carbonyls in the living rooms and bedrooms were formaldehyde, acetone, acetaldehyde, hexaldehyde and butyraldehyde. The median concentration levels in the living rooms and bedrooms were: 28.6 and 34.2 $\mu g\,m^{-3}$ for formaldehyde, 18.3 and 23.1 $\mu g\,m^{-3}$ for acetone, 14.3 and 15.8 $\mu g\,m^{-3}$ for acetaldehyde, 11.4 and 14.1 $\mu g\,m^{-3}$ for hexaldehyde and 10.8 and 12.4 $\mu g\,m^{-3}$ for butyraldehyde. The median concentration of formaldehyde, benzaldehyde, valeraldehyde and hexaldehyde was significantly higher in the bedrooms than in the living rooms. Indoor concentrations were significantly higher than outdoor concentrations for all carbonyl measured,

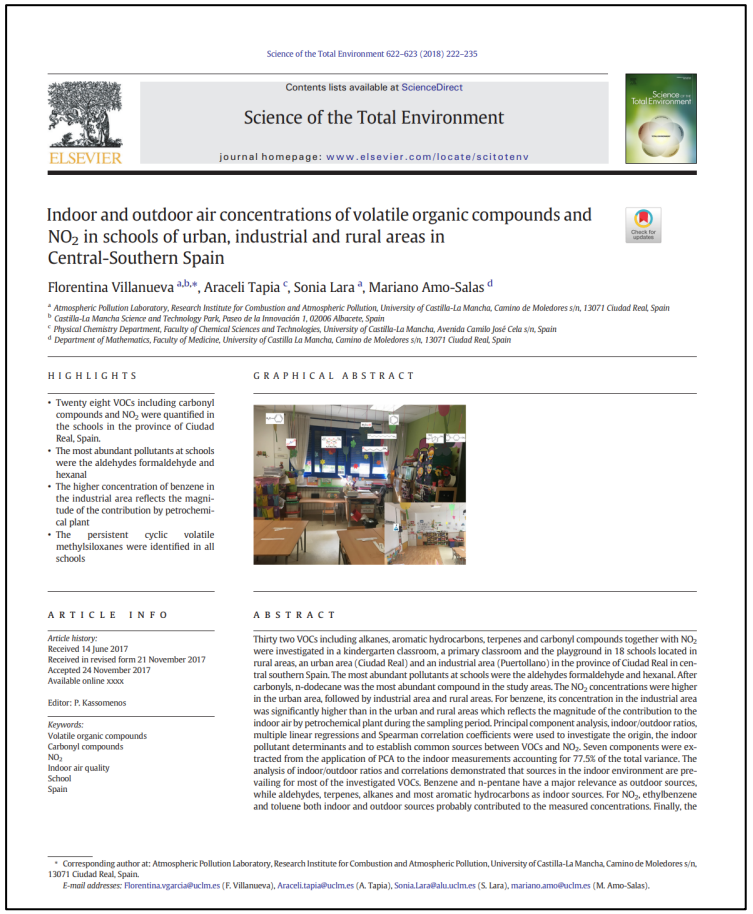
* Corresponding author. Universidad de Castilla La Mancha, Instituto de Investigación en Combustión y Contaminación Atmosférica, Camino de Moledores s/n, 13071, Ciudad Real, Spain.
E-mail addresses: Florentina.VGarcia@uclm.es (F. Villanueva), Sonia.laragomez@uclm.es (S. Lara), Alberto.notario@uclm.es (A. Notario), Mariano.amo@uclm.es (M. Amo-Salas), beatriz.cabanas@uclm.es (B. Cabañas).

https://doi.org/10.1016/j.chemosphere.2021.132429
Received 6 July 2021; Received in revised form 24 September 2021; Accepted 30 September 2021
Available online 1 October 2021
0045-6535/ © 2021 Elsevier Ltd. All rights reserved.

ESTUDIOS CONTAMINACIÓN DEL AIRE INTERIOR



- La mala calidad del aire en los colegios se ha relacionado con enfermedades respiratorias, asma, alergia y bajo rendimiento escolar.



Science of the Total Environment 622–623 (2018) 222–235

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Indoor and outdoor air concentrations of volatile organic compounds and NO_2 in schools of urban, industrial and rural areas in Central-Southern Spain

Florentina Villanueva [a,b,*], Araceli Tapia [c], Sonia Lara [a], Mariano Amo-Salas [d]

[a] Atmospheric Pollution Laboratory, Research Institute for Combustion and Atmospheric Pollution, University of Castilla-La Mancha, Camino de Moledores s/n, 13071 Ciudad Real, Spain
[b] Castilla-La Mancha Science and Technology Park, Paseo de la Innovación 1, 02006 Albacete, Spain
[c] Physical Chemistry Department, Faculty of Chemical Sciences and Technologies, University of Castilla-La Mancha, Avenida Camilo José Cela s/n, Spain
[d] Department of Mathematics, Faculty of Medicine, University of Castilla La Mancha, Camino de Moledores s/n, 13071 Ciudad Real, Spain

HIGHLIGHTS

- Twenty eight VOCs including carbonyl compounds and NO_2 were quantified in the schools in the province of Ciudad Real, Spain.
- The most abundant pollutants at schools were the aldehydes formaldehyde and hexanal
- The higher concentration of benzene in the industrial area reflects the magnitude of the contribution by petrochemical plant
- The persistent cyclic volatile methylsiloxanes were identified in all schools

GRAPHICAL ABSTRACT

ARTICLE INFO

Article history:
Received 14 June 2017
Received in revised form 21 November 2017
Accepted 24 November 2017
Available online xxxx

Editor: P. Kassomenos

Keywords:
Volatile organic compounds
Carbonyl compounds
NO_2
Indoor air quality
School
Spain

ABSTRACT

Thirty two VOCs including alkanes, aromatic hydrocarbons, terpenes and carbonyl compounds together with NO_2 were investigated in a kindergarten classroom, a primary classroom and the playground in 18 schools located in rural areas, an urban area (Ciudad Real) and an industrial area (Puertollano) in the province of Ciudad Real in central southern Spain. The most abundant pollutants at schools were the aldehydes formaldehyde and hexanal. After carbonyls, n-dodecane was the most abundant compound in the study areas. The NO_2 concentrations were higher in the urban area, followed by industrial area and rural areas. For benzene, its concentration in the industrial area was significantly higher than in the urban and rural areas which reflects the magnitude of the contribution to the indoor air by petrochemical plant during the sampling period. Principal component analysis, indoor/outdoor ratios, multiple linear regressions and Spearman correlation coefficients were used to investigate the origin, the indoor pollutant determinants and to establish common sources between VOCs and NO_2. Seven components were extracted from the application of PCA to the indoor measurements accounting for 77.5% of the total variance. The analysis of indoor/outdoor ratios and correlations demonstrated that sources in the indoor environment are prevailing for most of the investigated VOCs. Benzene and n-pentane have a major relevance as outdoor sources, while aldehydes, terpenes, alkanes and most aromatic hydrocarbons as indoor sources. For NO_2, ethylbenzene and toluene both indoor and outdoor sources probably contributed to the measured concentrations. Finally, the

* Corresponding author at: Atmospheric Pollution Laboratory, Research Institute for Combustion and Atmospheric Pollution, University of Castilla-La Mancha, Camino de Moledores s/n, 13071 Ciudad Real, Spain.
E-mail addresses: Florentina.vgarcia@uclm.es (F. Villanueva), Araceli.tapia@uclm.es (A. Tapia), Sonia.Lara@alu.uclm.es (S. Lara), mariano.amo@uclm.es (M. Amo-Salas).

ESTUDIOS CONTAMINACIÓN DEL AIRE INTERIOR

COVs y NO_2 en clases de infantil y primaria

RESULTADOS

28 COVs cuantificados y NO_2

Compuestos carbonílicos
Formaldehido, acetaldehído, acroleina/acetona, propanal, crotonaldehido, benzaldehído, pentanal, p-tolualdehído, hexanal

Alcanos
C5-C13, ciclohexano

Aromáticos
Benceno, tolueno, m,p-xileno, etilbenceno, estireno, 1,2,4-TMB

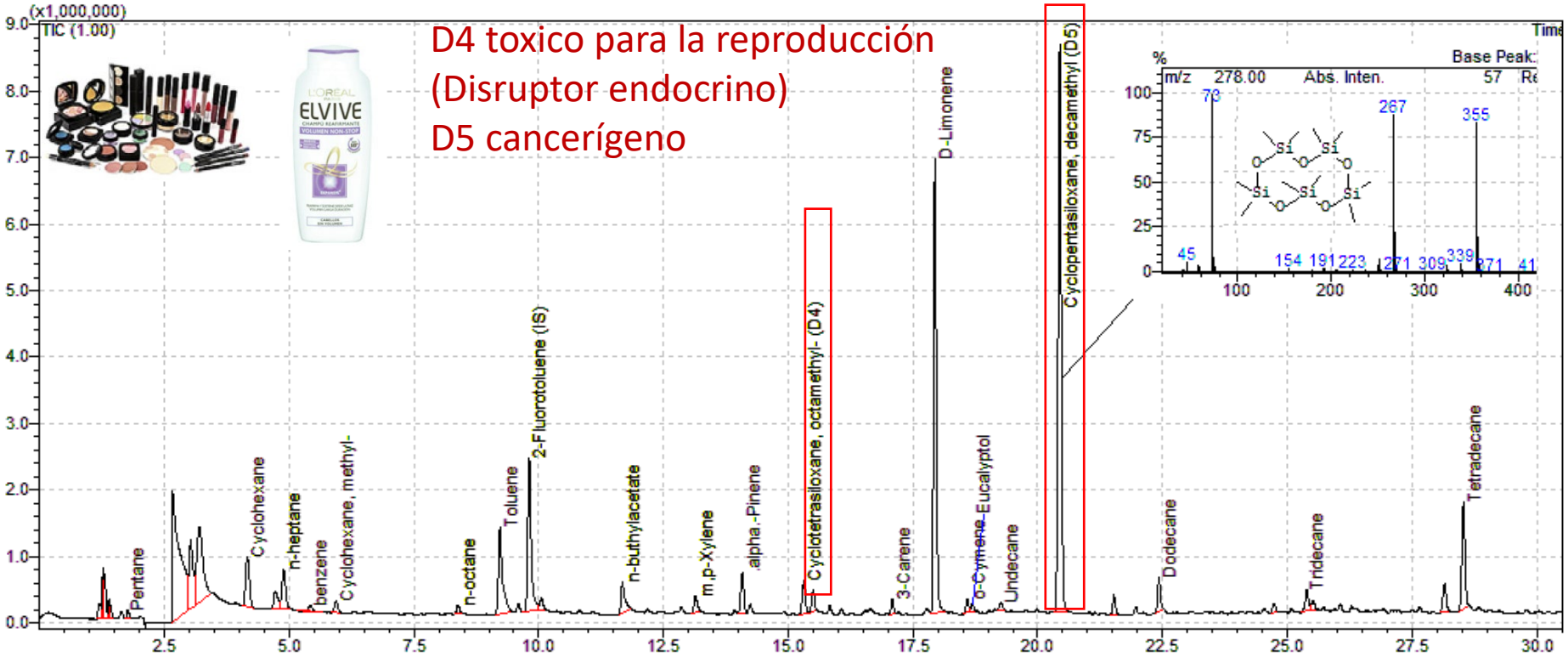
Terpenos
Limoneno
α-pineno

Otros COVs identificados gracias al GC-MS

n-etilacetato, n-butilacetato, metilciclohexano, etilciclohexano, 2-butoxietanol, canfeno, 3-careno, o-cimeno, eucaliptol, tedradecano y otros derivados de hidrocarburos

Siliconas volátiles (Organosiloxanos)
Octametilciclopentasiloxano (D4)
Decametilciclopentasiloxano (D5)

ESTUDIOS CONTAMINACIÓN DEL AIRE INTERIOR



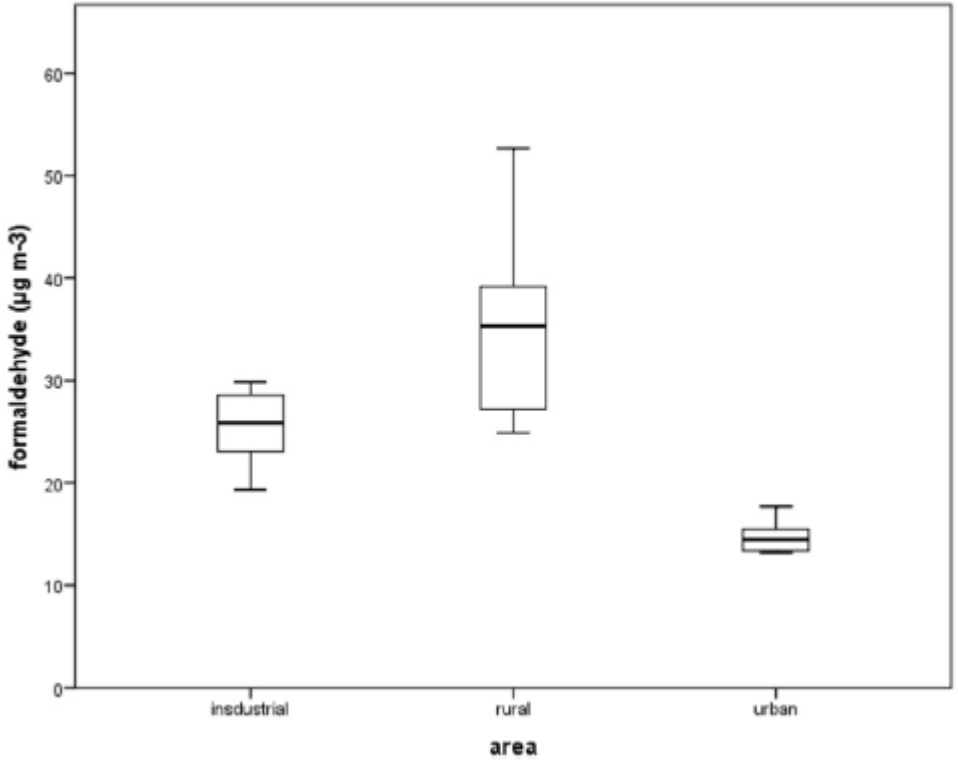
Los siloxanos D4, D5 y D6 también se utilizan de manera extensa en una gran variedad de productos cosméticos (cuidado de la piel, maquillaje, cuidado de cabello). La siliconas se utilizan por sus propiedades únicas que aportan brillo y suavidad al cabello.

Otros usos: adhesivos, envases alimentos, limpiadores, insecticidas, plásticos, dentales etc…

ESTUDIOS CONTAMINACIÓN DEL AIRE INTERIOR

COVs y NO_2 en clases de infantil y primaria

Compuestos carbonílicos: Formaldehido



- Formaldehido< 100 µg m^{-3} (OMS)
- rural>industrial>urbana con diferencias significativas en infantil

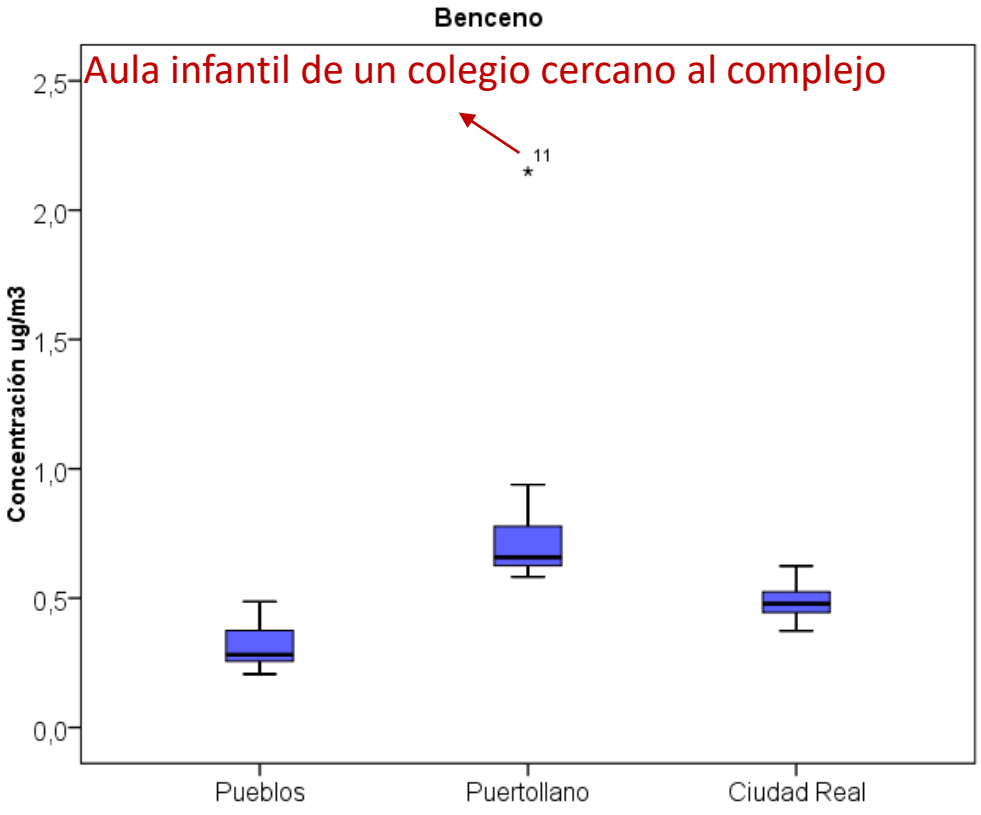
Residential Indoor Air Quality Guidelines for Formaldehydes

Exposure period	Concentration		Critical effect
	µg/m³	ppb	
1 hour	123	100	Eye irritation
8 hours	50	40	Respiratory symptoms in children

HEALTH CANADA

ESTUDIOS CONTAMINACIÓN DEL AIRE INTERIOR

COVs y NO_2 en clases de infantil y primaria



< 1 µg m^{-3} excepto en un aula de infantil de un colegio cercano al complejo petroquímico (2,1 µg m^{-3})

BENCENO: NO HAY UN LIMITE POR DEBAJO DEL CUAL SEA SEGURO PARA LA SALUD (OMS, 2010)

La industria pretroquímica SI influyó sobre la atmosfera de Puertollano durante el periodo de medida

EXTERIOR:

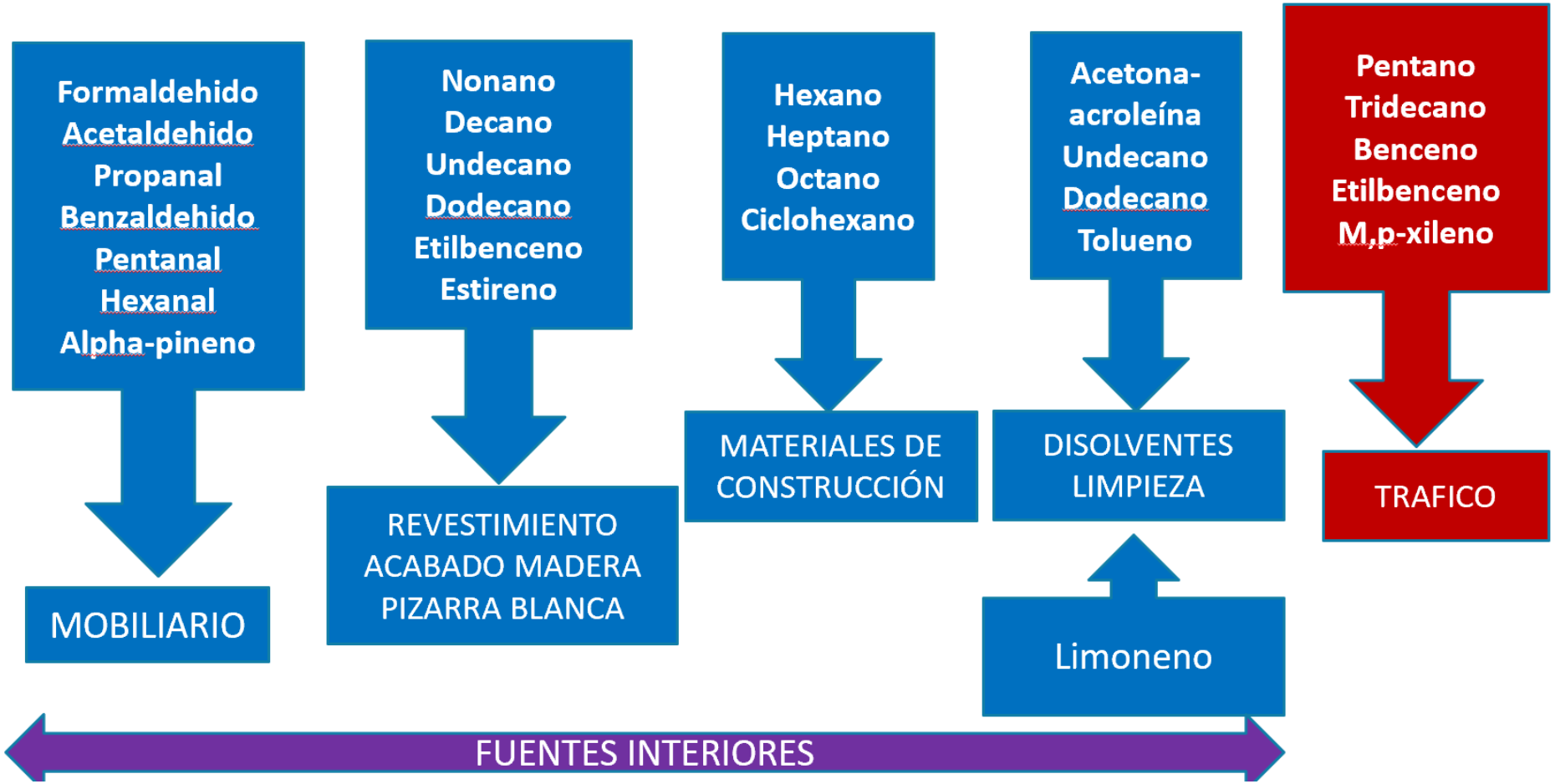
BENCENO/TOLUENO Puertollano (0,78); Ciudad Real (0,49) y zonas rurales (0,62)

RATIO = 0,5 ORIGEN EN EL TRAFICO

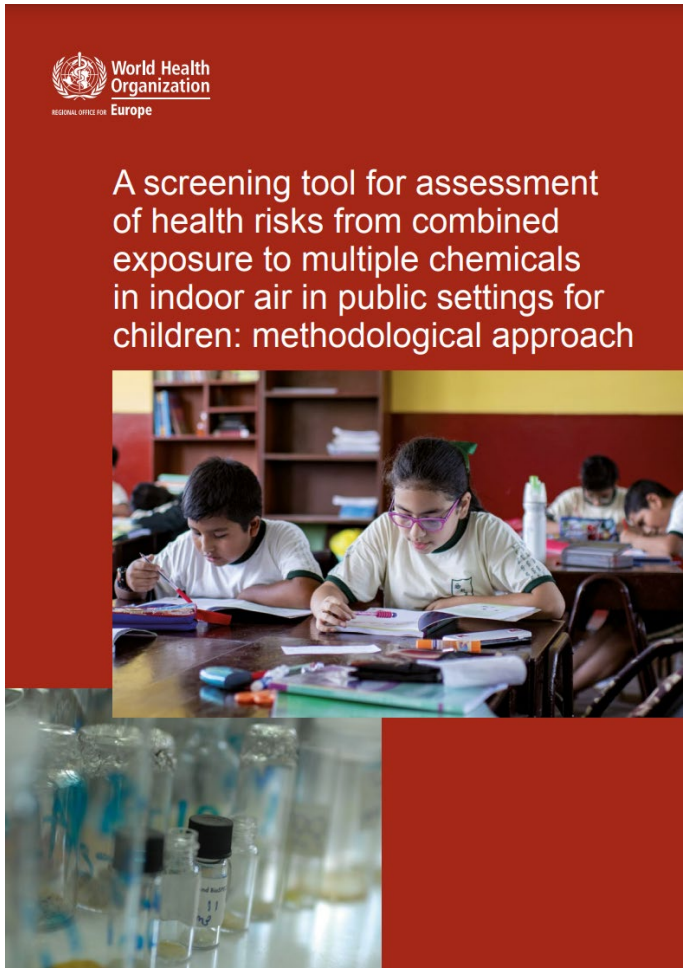
ESTUDIOS CONTAMINACIÓN DEL AIRE INTERIOR

COVs y NO_2 en clases de infantil y primaria

IDENTIFICACIÓN DE LAS FUENTES (ANÁLISIS DE COMPONENETES PRINCIPALES-SPSS)

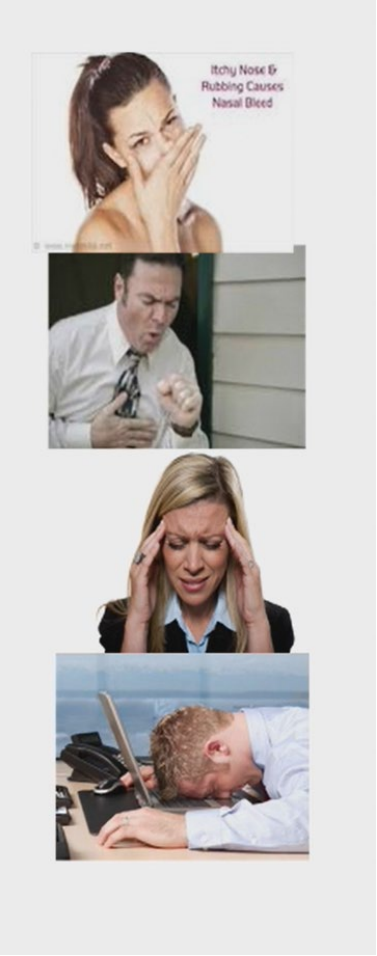


CONTAMINACIÓN DEL AIRE INTERIOR Y SALUD



ORGANIZACIÓN MUNDIAL DE LA SALUD (OMS)-2018.
Desarrollo de una herramienta para calcular el riesgo acumulativo de la exposición a contaminantes del aire interior en los colegios

Sistema respiratorio
Sistema nervioso
Sistema cardiovascular
Carcinogenicidad
Irritación del sistema respiratorio



A screening tool for assessment of health risks from combined exposure to multiple chemicals in indoor air in public settings for children: methodological approach

ANNEX 1. LIST OF PRIORITY CHEMICALS INCLUDED IN THE SCREENING TOOL FOR ASSESSMENT OF RISK OF COMBINED EXPOSURE TO HAZARDOUS CHEMICALS

No.	Chemical family		Substances	Chemical Abstracts Services (CAS) number
1	**Oxygenated volatile organic compounds (oxy-VOCs)**	Aldehydes	Formaldehyde	50-00-0
2			Acetaldehyde	75-07-0
3	**Volatile organic compounds (VOCs)**	Aromatic hydrocarbons	Benzene	71-43-2
4			Ethylbenzene	100-41-4
5			xylene (o-, m-, p-)	95-47-6 108-38-3/106-42-3
6			Styrene	100-42-5
7			Toluene	108-88-3
8			1,2,3-trimethylbenzene	526-73-8
9			1,4-dichlorobenzene	106-46-7
10		Esters	Butyl acetate	123-86-4
11		Terpenes	Limonene	138-86-3
12			α-pinene	80-56-8
13		Chlorinated hydrocarbons	Tetrachloroethylene	127-18-4
14			Trichloroethylene	79-01-6
15		Polycyclic aromatic hydrocarbons (PAHs)	Naphthalene	91-20-3
16	**Semi-volatile organic compounds (SVOCs)**	PAHs	Benzo(a)pyrene	50-32-8
17	**Inorganic compounds**	Nitrogen dioxide (NO_2)	NO_2	10102-44-0

La lista inicial de contaminantes medidos en aulas de países europeos incluía 100 compuestos

ANNEX 2. OTHER POLLUTANTS OF CONCERN IN INDOOR AIR

No.	Chemical family	Substances
1	**Particulate matter**	Particulate matter with an aerodynamic diameter below 10 µm (PM_{10})
2		Particulate matter with an aerodynamic diameter below 2.5 µm ($PM_{2.5}$)
3	**Inorganic compounds**	Carbon monoxide (CO)
4		Ozone (O_3)
5	**Phthalates**	Diethyl phthalate (DEP)
6		Diisobutyl phthalate (DiBP)
7		Di-n-butyl phthalate (DnBP)
8	**Musks**	Galaxolide
9		Tonalide
10	**PAHs**	Acenaphthene
11		Acenaphthylene
12		Phenantrene
13		Anthracene
14		Benz[a]anthracene
15		Benzo[b]fluoranthene
16		Benzo[j]fluoranthene
17		Benzo[e]pyrene
18		Benzo[ghi]perylene
19		Benzo[k]fluoranthene
20		Chrysene
21		Dibenz[a,h]anthracene
22		Dibenzo[a,l]pyrene
23		Fluoranthene
24		Fluorene
25		Indeno[1,2,3-cd]pyrene
26		Pyrene
27	**Brominated flame retardants (BFRs)–polybrominated diphenyl ethers (PBDEs)**	2,4,4'-tribromodiphenyl ether (BDE 28)
28		2,2',4,4'-tetrabromodiphenyl ether (BDE 47)
29		2,2',4,4',5-pentabromodiphenyl ether (BDE 99)
30		2,2',4,4',6-pentabromodiphenyl ether (BDE 100)
31		2,2',4,4',5,5'-hexabromodiphenyl ether (BDE 153)
32		2,2',3,4,4',5',6-heptabromodiphenyl ether (BDE 183)
33		2,2',3,3',4,4',5,5',6,6'-decabromodiphenyl ether (BDE 209)
34		1,2-dibromo-4-(1,2-dibromoethyl)cyclohexane (DBE-DBCH)

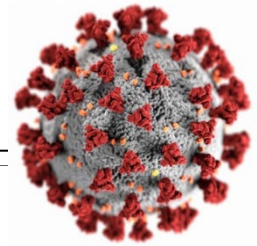
No.	Chemical family	Substances
35	**Organophsophate flame retardants (OPFRs)**	Tributyl phosphate (TBP)
36		Tris(2-butoxyethyl) phosphate (TBEP)
37		Tris(1-chloropropan-2-yl) phosphate (TCPP)
38		Tris(2-chloroethyl) phosphate (TCEP)
39	**Chlorinated paraffins (CPs)**	Short-chain CPs (SCCPs) (C_{10-13})
40		Medium-chain CPs (MCCPs) (C_{14-17})
41		Long-chain CPs (LCCPs) (C_{18-30})

PARQUE CIENTÍFICO Y TECNOLÓGICO DE CASTILLA - LA MANCHA

ICCA INSTITUTO DE INVESTIGACIÓN EN COMBUSTIÓN Y CONTAMINACIÓN ATMOSFÉRICA

I. Evaluación de CO_2 y aerosoles (PM_{10}, $PM_{2.5}$, UFP) durante la reapertura de los colegios

II. Vigilancia ambiental del SAR-CoV-2 mediante equipos de filtros HEPA



Environmental Research 197 (2021) 111092

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Assessment of CO_2 and aerosol ($PM_{2.5}$, PM_{10}, UFP) concentrations during the reopening of schools in the COVID-19 pandemic: The case of a metropolitan area in Central-Southern Spain

Florentina Villanueva[a,b], Alberto Notario[a,c], Beatriz Cabañas[a,c], Pilar Martín[a,c], Sagrario Salgado[a,c], Marta Fonseca Gabriel[d,*]

[a] Universidad de Castilla La Mancha, Instituto de Investigación en Combustión y Contaminación Atmosférica, Camino de Moledores s/n, 13071, Ciudad Real, Spain
[b] Parque Científico y Tecnológico de Castilla La Mancha, Paseo de la Innovación 1, 02006, Albacete, Spain
[c] Universidad de Castilla La Mancha, Departamento de Química Física, Facultad de Ciencias y Tecnologías Químicas, Avenida Camilo José Cela s/n, 13071, Ciudad Real, Spain
[d] INEGI, Institute of Science and Innovation in Mechanical and Industrial Engineering, Campus da FEUP, Rua Dr. Roberto Frias 400, 4200-465, Porto, Portugal

ARTICLE INFO

Keywords:
COVID-19 pandemic
Particulate matter
SARS-CoV-2 transmission risk mitigation
School environment
Ventilation conditions

ABSTRACT

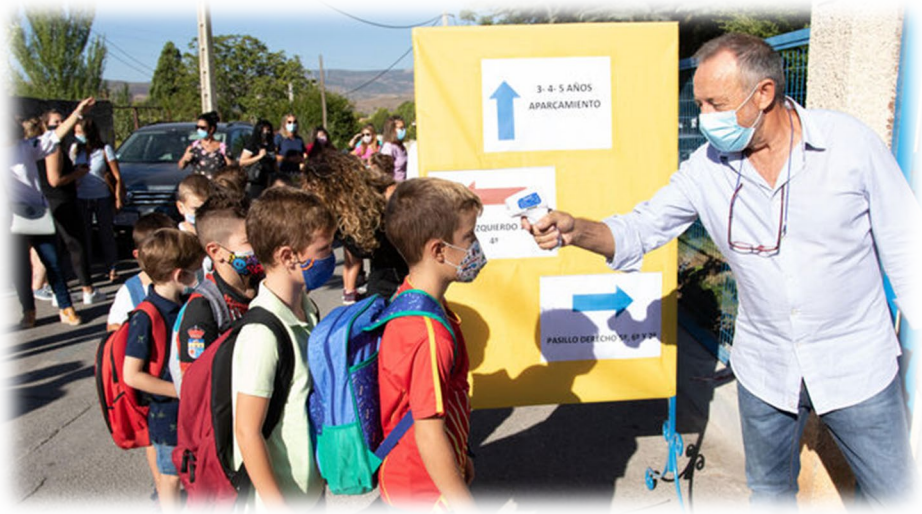
Public health authorities have been paramount in guaranteeing that adequate fresh air ventilation is promoted in classrooms to avoid SARS-CoV-2 transmission in educational environments. In this work it was aimed to assess ventilation conditions (carbon dioxide, CO_2) and suspended particulate matter ($PM_{2.5}$, PM_{10} and UFP) levels in 19 classrooms – including preschool, primary and secondary education – located in the metropolitan area of Ciudad Real, Central-Southern Spain, during the school's reopening (from September 30th until October 27th, 2020) after about 7 months of lockdown due to COVID-19 pandemic. The classrooms that presented the worst indoor environmental conditions, according to the highest peak of concentration obtained, were particularly explored to identify the possible influencing factors and respective opportunities for improvement. Briefly, findings suggested that although ventilation promoted through opening windows and doors according to official recommendations is guaranteeing adequate ventilation conditions in most of the studied classrooms, thus minimizing the risk of SARS-CoV-2 airborne transmission, a total of 5 (26%) surveyed classrooms were found to exceed the recommended CO_2 concentration limit value (700 ppm). In general, preschool rooms were the educational environments that registered better ventilation conditions, while secondary classrooms exhibited the highest peak and average CO_2 concentrations. In turn, for $PM_{2.5}$, PM_{10} and UFP, the concentrations assessed in preschools were, on average about 2-fold greater than the levels obtained in both primary and secondary classrooms. In fact, the indoor $PM_{2.5}$ and PM_{10} concentrations substantially exceeded the recommended limits of 8hr-exposure, established by WHO, in 63% and 32% of the surveyed classrooms, respectively. Overall, it is expected that the findings presented in this study will assist the establishment of evidence-based measures (namely based on ensuring proper ventilation rates and air filtration) to mitigate preventable environmental harm in public school buildings, mainly at local and national levels.

1. Introduction

The causative pathogen of the COVID-19 outbreak has been identified as a highly infectious novel coronavirus referred as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) with origin in Wuhan (December 2019) that continues to spread globally. On February 11th, the first two cases were confirmed in Spain. These were labelled as imported cases of infection, since they were related to contacts with confirmed cases of SARS-CoV-2 in Germany and France (ISCIII, 2020a). At that time, 44,554 cases were confirmed by the WHO (44,235 in China and 319 in the rest of the world - 37 in the European Union), including 910 deaths among the confirmed cases (908 in China and 1 outside of China) (ISCIII, 2020a). The first official death from COVID-19 reported in Spain occurred on February 13th and consisted of a 69-years-old man who previously travelled to Nepal (ISCIII, 2020b). Until October 28th, 2020, a total of 1,136,503 confirmed cases and 35,466 deaths have been

* Corresponding author. Energy Group (INEGI), Campus da FEUP, Rua Dr. Roberto Frias 400, 4200-465, Porto, Portugal.
E-mail address: mgabriel20023@gmail.com (M.F. Gabriel).

https://doi.org/10.1016/j.envres.2021.111092
Received 13 January 2021; Received in revised form 25 February 2021; Accepted 24 March 2021
Available online 27 March 2021
0013-9351/© 2021 Elsevier Inc. All rights reserved.



Received: 15 March 2022 | Revised: 20 August 2022 | Accepted: 24 August 2022
DOI: 10.1111/ina.13109

ORIGINAL ARTICLE

HEPA filters of portable air cleaners as a tool for the surveillance of SARS-CoV-2

Isabel G. Fernández de Mera[1] | Carmen Granda[2] | Florentina Villanueva[3,4] | Marta Sánchez-Sánchez[1] | Alberto Moraga-Fernández[1] | Christian Gortázar[1] | José de la Fuente[1,5]

[1]SaBio, Instituto de Investigación en Recursos Cinegéticos IREC (UCLM-CSIC-JCCM), Ronda de Toledo, Ciudad Real, Spain
[2]Residencias CADIG Guadiana I y II, Centro de Salud Ciudad Real I, Spain
[3]Instituto de Investigación en Combustión y Contaminación Atmosférica, Universidad de Castilla-La Mancha, Ciudad Real, Spain
[4]Parque Científico y Tecnológico de Castilla-La Mancha, Paseo de la Innovación 1, Albacete, Spain
[5]Department of Veterinary Pathobiology, Center for Veterinary Health Sciences, Oklahoma State University, Stillwater, Oklahoma, USA

Correspondence
Florentina Villanueva, Instituto de Investigación en Combustión y Contaminación Atmosférica, Universidad de Castilla-La Mancha, Ciudad Real, Spain.
Email: florentina.vgarcia@uclm.es

Funding information
Diputación de Ciudad Real; Fundación Eurocaja Rural

Abstract

Studies about the identification of SARS-CoV-2 in indoor aerosols have been conducted in hospital patient rooms and to a lesser extent in nonhealthcare environments. In these studies, people were already infected with SARS-CoV-2. However, in the present study, we investigated the presence of SARS-CoV-2 in HEPA filters housed in portable air cleaners (PACs) located in places with apparently healthy people to prevent possible outbreaks. A method for detecting the presence of SARS-CoV-2 RNA in HEPA filters was developed and validated. The study was conducted for 13 weeks in three indoor environments: school, nursery, and a household of a social health center, all in Ciudad Real, Spain. The environmental monitoring of the presence of SARS-CoV-2 was conducted in HEPA filters and other surfaces of these indoor spaces for a selective screening in asymptomatic population groups. The objective was to limit outbreaks at an early stage. One HEPA filter tested positive in the social health center. After analysis by RT-PCR of SARS-CoV-2 in residents and healthcare workers, one worker tested positive. Therefore, this study provides direct evidence of virus-containing aerosols trapped in HEPA filters and the possibility of using these PACs for environmental monitoring of SARS-CoV-2 while they remove airborne aerosols and trap the virus.

KEYWORDS
aerosols, HEPA filter, indoor air, portable air cleaners, SARS-CoV-2, surveillance

1 | INTRODUCTION

On March 11, 2020, the World Health Organization (WHO) declared officially a global pandemic caused by coronavirus disease 2019 (COVID-19), a highly transmittable and pathogenic viral infection caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).[1,2]

In Spain, schools and many nurseries re-opened in September 2020 after 7 months of lockdown with the establishment of rigorous infection control practices, mainly by promoting frequent hand hygiene, guaranteeing periodic cleaning of surfaces, physical distance of at least 1.5 m, and increasing ventilation of the indoor spaces by opening windows and doors. In fact, the ventilation conditions during the first month of reopening schools in classrooms surveyed in Ciudad Real (Spain) were greatly better than those reported previously in the literature, being the median concentration of CO_2 of 539 ppm for preschools and 565 ppm for primary classrooms.[3]

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.
© 2022 The Authors. *Indoor Air* published by John Wiley & Sons Ltd.

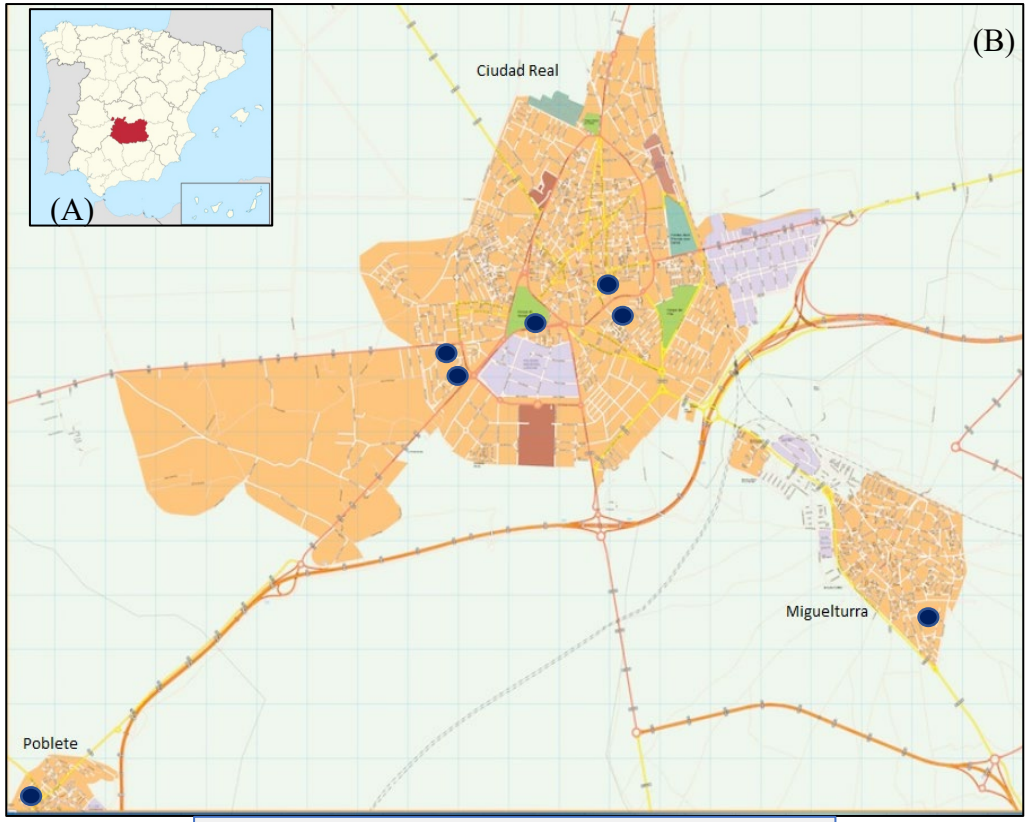
PARQUE CIENTÍFICO Y TECNOLÓGICO DE CASTILLA - LA MANCHA

ICCA INSTITUTO DE INVESTIGACIÓN EN COMBUSTIÓN Y CONTAMINACIÓN ATMOSFÉRICA

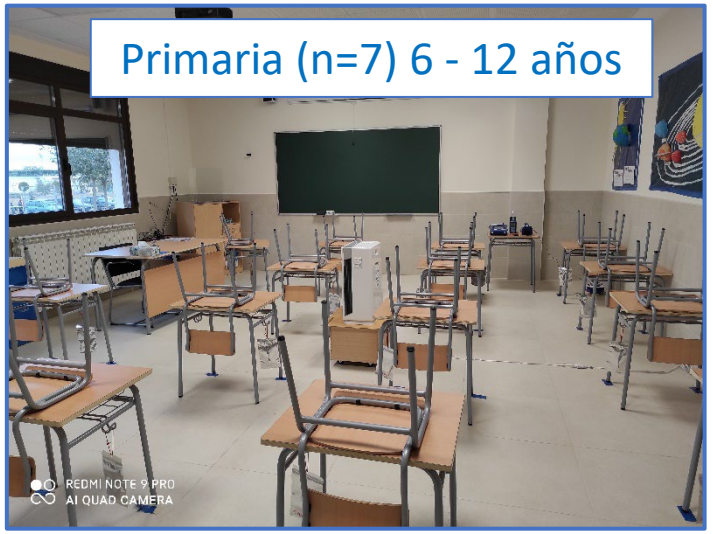
EVALUACIÓN DEL CO_2 Y AEROSOLES EN LA REAPERTURA DE LOS COLEGIOS EN 2020

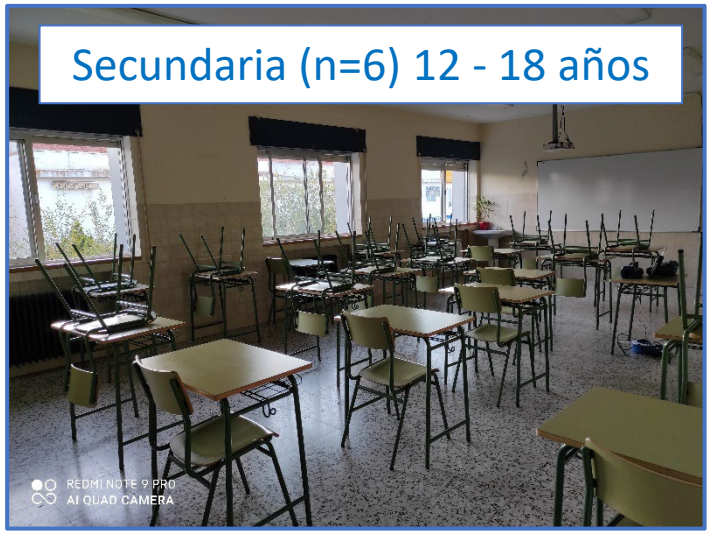
7 colegios

Plan de Evaluación: octubre - diciembre



- Comfort conditions (T and RH)
- Ventilation conditions (CO_2)
- Airborne particle concentration (PM_{10}, $PM_{2.5}$, and UFP)





EQUIPOS PORTATILES CON FILTROS HEPA Y DE CARBÓN ACTIVO

Received: 15 March 2022 | Revised: 20 August 2022 | Accepted: 24 August 2022
DOI: 10.1111/ina.13109

ORIGINAL ARTICLE

WILEY

HEPA filters of portable air cleaners as a tool for the surveillance of SARS-CoV-2

Isabel G. Fernández de Mera[1] | Carmen Granda[2] | Florentina Villanueva[3,4] | Marta Sánchez-Sánchez[1] | Alberto Moraga-Fernández[1] | Christian Gortázar[1] | José de la Fuente[1,5]

[1]SaBio, Instituto de Investigación en Recursos Cinegéticos IREC (UCLM-CSIC-JCCM), Ronda de Toledo, Ciudad Real, Spain
[2]Residencias CADIG Guadiana I y II, Centro de Salud Ciudad Real I, Spain
[3]Instituto de Investigación en Combustión y Contaminación Atmosférica, Universidad de Castilla-La Mancha, Ciudad Real, Spain
[4]Parque Científico y Tecnológico de Castilla-La Mancha, Paseo de la Innovación 1, Albacete, Spain
[5]Department of Veterinary Pathobiology, Center for Veterinary Health Sciences, Oklahoma State University, Stillwater, Oklahoma, USA

Correspondence
Florentina Villanueva, Instituto de Investigación en Combustión y Contaminación Atmosférica, Universidad de Castilla-La Mancha, Ciudad Real, Spain.
Email: florentina.vgarcia@uclm.es

Funding information
Diputación de Ciudad Real; Fundación Eurocaja Rural

Abstract
Studies about the identification of SARS-CoV-2 in indoor aerosols have been conducted in hospital patient rooms and to a lesser extent in nonhealthcare environments. In these studies, people were already infected with SARS-CoV-2. However, in the present study, we investigated the presence of SARS-CoV-2 in HEPA filters housed in portable air cleaners (PACs) located in places with apparently healthy people to prevent possible outbreaks. A method for detecting the presence of SARS-CoV-2 RNA in HEPA filters was developed and validated. The study was conducted for 13 weeks in three indoor environments: school, nursery, and a household of a social health center, all in Ciudad Real, Spain. The environmental monitoring of the presence of SARS-CoV-2 was conducted in HEPA filters and other surfaces of these indoor spaces for a selective screening in asymptomatic population groups. The objective was to limit outbreaks at an early stage. One HEPA filter tested positive in the social health center. After analysis by RT-PCR of SARS-CoV-2 in residents and healthcare workers, one worker tested positive. Therefore, this study provides direct evidence of virus-containing aerosols trapped in HEPA filters and the possibility of using these PACs for environmental monitoring of SARS-CoV-2 while they remove airborne aerosols and trap the virus.

KEYWORDS
aerosols, HEPA filter, indoor air, portable air cleaners, SARS-CoV-2, surveillance

1 | INTRODUCTION

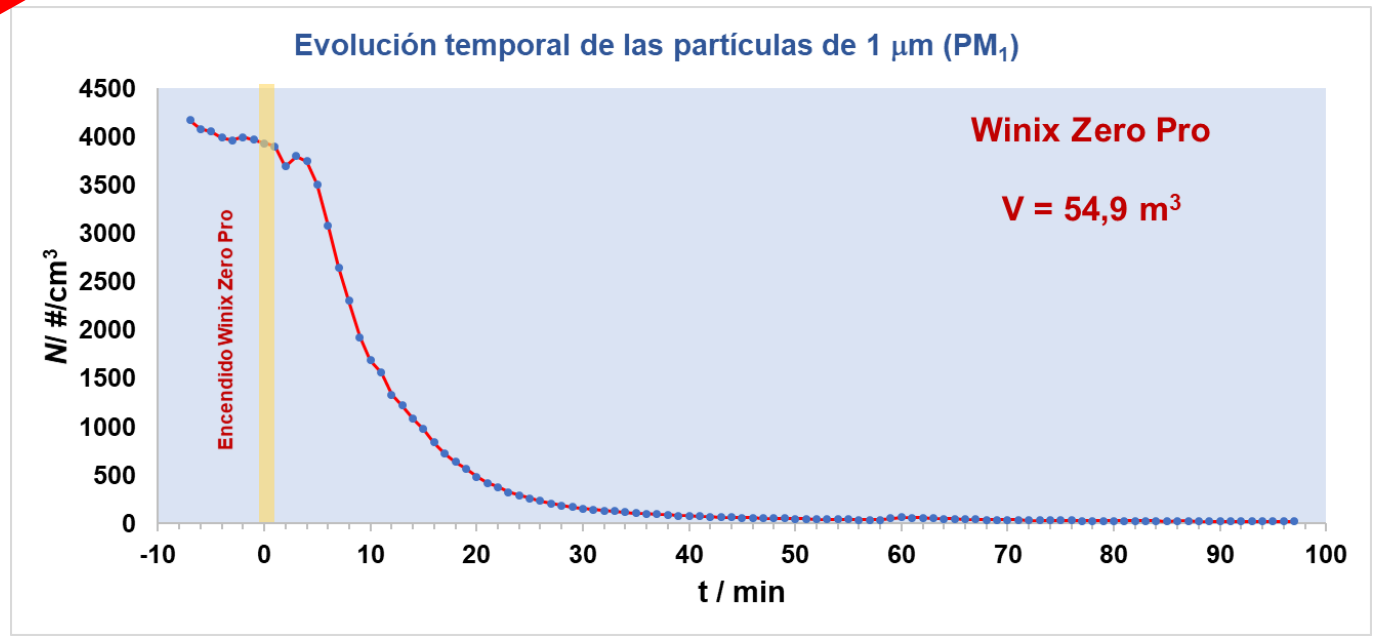
On March 11, 2020, the World Health Organization (WHO) declared officially a global pandemic caused by coronavirus disease 2019 (COVID-19), a highly transmittable and pathogenic viral infection caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).[1,2]

In Spain, schools and many nurseries re-opened in September 2020 after 7 months of lockdown with the establishment of rigorous infection control practices, mainly by promoting frequent hand hygiene, guaranteeing periodic cleaning of surfaces, physical distance of at least 1.5 m, and increasing ventilation of the indoor spaces by opening windows and doors. In fact, the ventilation conditions during the first month of reopening schools in classrooms surveyed in Ciudad Real (Spain) were greatly better than those reported previously in the literature, being the median concentration of CO_2 of 539 ppm for preschools and 565 ppm for primary classrooms.[3]

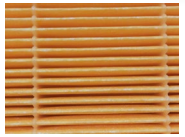
This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.
© 2022 The Authors. *Indoor Air* published by John Wiley & Sons Ltd.

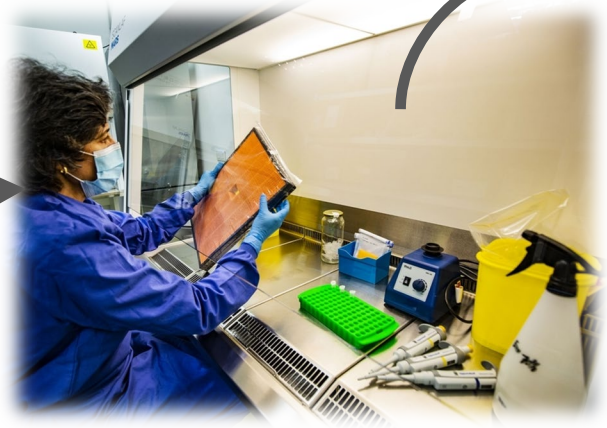
CARACTERÍSTICAS:

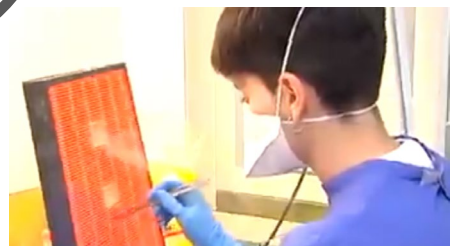
- CADR: 470 m^3/h
- HEPA H13
- Certificado ECARF
- Certificado AHAM



II. VIGILANCIA AMBIENTAL MEDIANTE EQUIPOS DE FILTROS HEPA







GRUPO DE INVESTIGACIÓN DE SANIDAD Y BIOTECNOLOGÍA (SABIO) DE LA UCLM.

II. VIGILANCIA AMBIENTAL DEL SARS-CoV-2 MEDIANTE EQUIPOS DE FILTROS HEPA

Durante las 13 semanas de estudio:

Colegio

Guardería

NEGATIVOS

Residencia

Detección de 1 caso asintomático POSITIVO

Por tanto, este estudio proporcionó evidencia dierecta de aerosoles que contienen el virus atrapado en los filtros HEPA y la posibilidad de emplear los purificadores de aire con filtros HEPA para la monitorización atmosférica del SARS-CoV-2 al mismo tiempo que eliminan el virus del aire y lo atrapan.

EQUIPOS PORTATILES CON FILTROS HEPA Y DE CARBÓN ACTIVO

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Review

Portable air purification: Review of impacts on indoor air quality and health

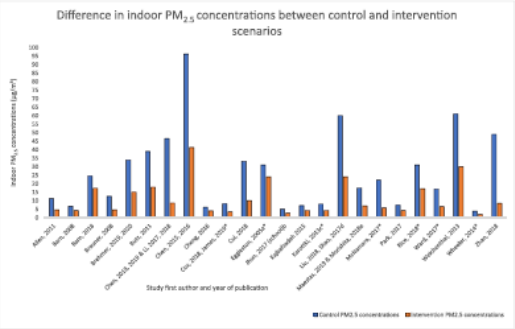
Emily Cheek [1], Valentina Guercio [1], Clive Shrubsole, Sani Dimitroulopoulou *

Air Quality and Public Health Group, Environmental Hazards and Emergencies Department, Centre for Radiation, Chemical and Environmental Hazards, Public Health England, Harwell Campus, Didcot, Oxfordshire, United Kingdom

HIGHLIGHTS

- Due to time spent indoors, buildings are important modifiers of population health
- Where source control is not possible, pollution mitigation strategies are required
- Portable air purifiers with filtration reduce indoor $PM_{2.5}$ concentrations
- Current epidemiological evidence on health impacts is limited and inconsistent
- Costly interventions for vulnerable groups must avoid increasing health inequalities

GRAPHICAL ABSTRACT

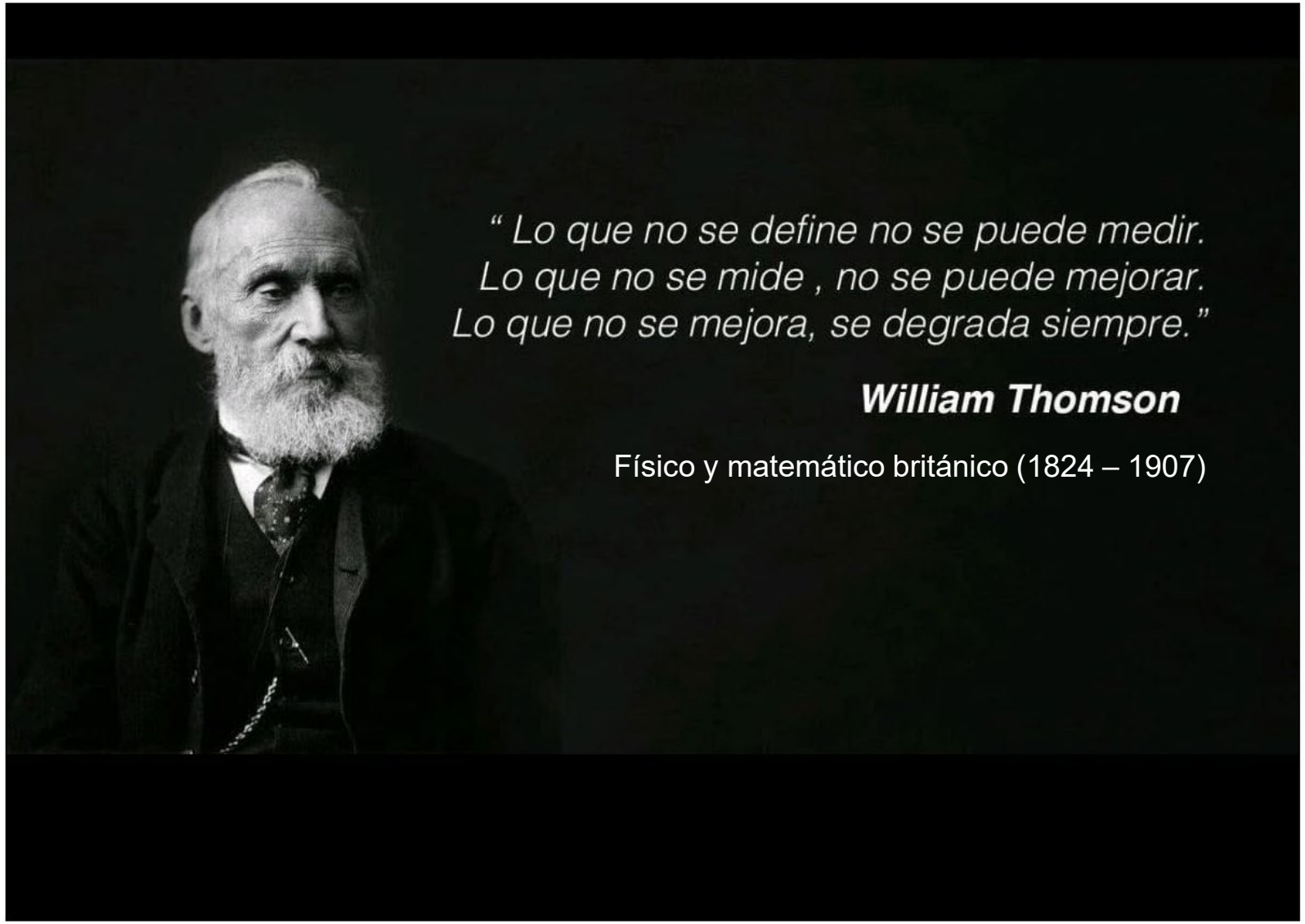


ABSTRACT

A systematic literature review was carried out to examine the impact of portable air purifiers (PAPs) on indoor air quality ($PM_{2.5}$) and health, focussing on adults and children in indoor environments (homes, schools and offices). Analysed studies all showed reductions in $PM_{2.5}$ of between 22.6 and 92.0% with the use of PAPs when compared to the control. Associations with health impacts found included those on blood pressure, respiratory parameters and pregnancy outcomes. Changes in clinical biochemical markers were also identified. However, evidence for such associations was limited and inconsistent. Health benefits from a reduction in $PM_{2.5}$ would be expected as the cumulative body of scientific evidence from various cohort studies shows positive impacts of long-term reduction in $PM_{2.5}$ concentrations. The current evidence demonstrates that using a PAP results in short-term reductions in $PM_{2.5}$ in the indoor environment, which has the potential to offer health benefits.

Crown Copyright © 2020 Published by Elsevier B.V. All rights reserved.

MEJORA LA CALIDAD DEL AIRE EN LOS AMBIENTES INTERIORES EN CUANTO A LA REDUCCIÓN DE MATERIAL PARTICULADO POR LO QUE ES DE ESPERAR QUE RESULTE EN BENEFICIOS PARA LA SALUD.


" Lo que no se define no se puede medir.
Lo que no se mide , no se puede mejorar.
Lo que no se mejora, se degrada siempre."
William Thomson
Físico y matemático británico (1824 – 1907)

PARQUE CIENTÍFICO
Y TECNOLÓGICO
DE CASTILLA - LA MANCHA

ICCA
INSTITUTO DE INVESTIGACIÓN EN COMBUSTIÓN Y CONTAMINACIÓN ATMOSFÉRICA

Instituto de Investigación en Combustión y Contaminación Atmosférica

UNIVERSIDAD DE CASTILLA LA MANCHA
Florentina.vgarcia@uclm.es
@FloriVilla3