

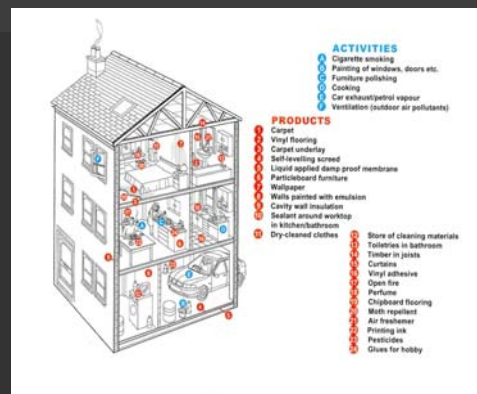


Representative surveys of air pollutants in English homes

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Indoor pollution

- Indoor air pollution is the presence in buildings of toxic or other substances which may directly or indirectly be a cause of occupant ill health or discomfort.
- Organic chemicals (formaldehyde, VOCs)
- Inorganic gases e.g. NO₂, CO
- Particulates e.g. PM₁₀, nano and fibres
- Biological particulates e.g. fungi, bacteria, pollen, allergens
- Radon
- Excess humidity

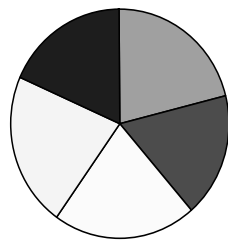


What is representative of the housing stock representative?

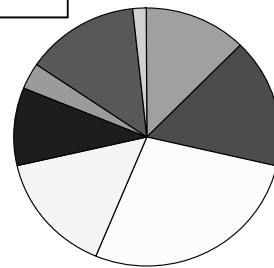
- 21 million dwellings in England
- Differ by location, age, type of structure, shape and configuration, occupancy, furnishings etc.
- English House Condition Survey (EHCS) surveys each year randomly selected dwellings throughout England and is basis for government determining the resource allocation for housing

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Characteristics of dwellings in England; 2001



■ pre 1919
■ 1919-1944
□ 1945-1964
□ 1965-1980
■ post 1980



■ Small terraced house
■ Medium/large terraced house
□ Semi-detached house
□ Detached house
■ Bungalow
□ Converted flat
■ Purpose built flat, low rise
□ Purpose built flat, high rise

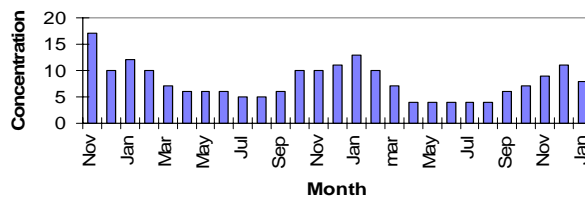
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ALSPAC

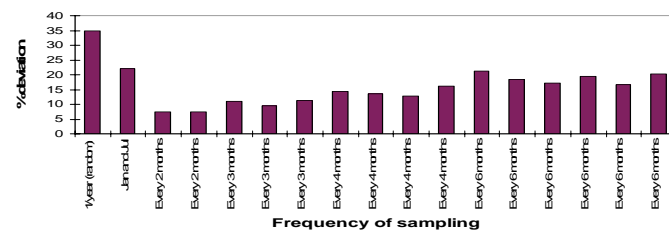
- Avon Longitudinal Study of Pregnancy and Childhood
- 174 randomly selected pregnant mothers participated in monitoring of IAQ over a 12 month period pre and post natal during 1991/92
- Part of larger study of nearly 14,000 mothers in Avon area (in and around Bristol)
- Formaldehyde, VOCs, NO₂, bacteria, fungi and mites measured each month
- Questionnaires about activities in the home and health of mother and baby

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ALSPAC Study; Mean Monthly Benzene Concentration in Main Bedrooms for All Homes (ug/m3)



ALSPAC study; Comparison of Mean Deviation From the Annual Mean Benzene Concentration Resulting from the Use of Different Sampling Strategies



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IAQ Survey of England

Objectives

- To extend and refine knowledge of baseline levels of indoor pollutants in homes (previous BRE studies of 174 homes in Avon, 40 in Southampton, 400 in Nottingham).
- To identify any regional differences in pollutant levels
- To permit a detailed analysis of factors associated with high indoor pollutant concentrations

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Selection of homes

- Homes selected as a sub-sample of the Survey of English Homes Oct 1997 - Feb 1999 undertaken by ONS.
- 168 homes in England selected at random invited to join study each month (2,856 total)
- around 80 per month accepted (1,360 total)
- 876 participated successfully

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Sampling strategy

- Questionnaire on house characteristics, activities etc and instructions on operating samplers administered by ONS interviewer.
- NO₂ Palmes tube; kitchen, bedroom, outside; 2 weeks
- CO Draeger tube; kitchen, bedroom; 2 weeks
- Formaldehyde; GMD dosimeter, bedroom, 3 days
- VOCs; Tenax TA tube; bedroom, 4 weeks (TVOCs and 22 individual VOCs)
- Total of 6,000+ samples and ~1,700 questionnaires during project.

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Diffusive sampling methods



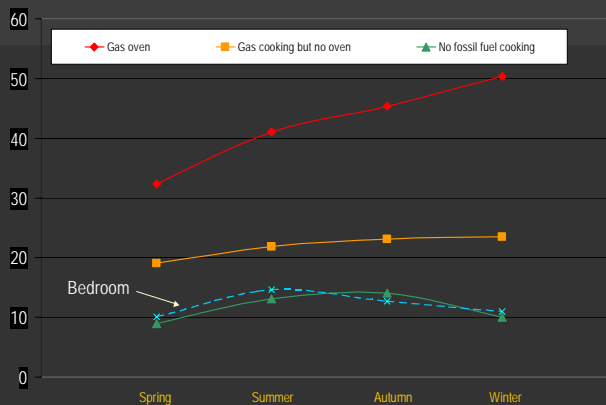
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Results of measurements of concentrations in homes in IAQ survey of England

compound	concentration $\mu\text{g m}^{-3}$		
	GM	10 th percentile	95 th percentile
NO ₂	11.9	4.4	38
CO	390	120	1680
Formaldehyde	22.2	9.8	61
TVOC	210	72	1010
Benzene	3	1	14.6
Toluene	15.1	4.4	74.9
limonene	6.2	1.3	51

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Results - NO₂ (Kitchen - $\mu\text{g m}^{-3}$)



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Overview of main findings - NO₂

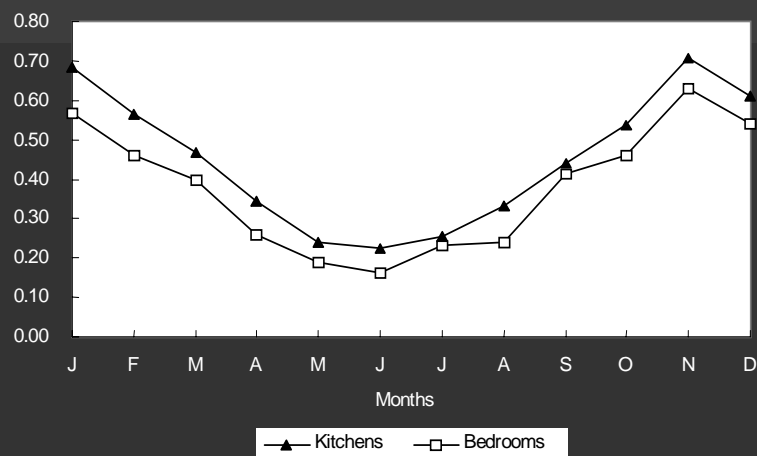
- The following factors were found to have a causal effect on NO₂ levels:

- season
- cooking fuel
- dwelling type
- area type
- heating type

- the following had a small but significant effect; smoking, extract fan, condensation, household size, number of habitable rooms

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Results - CO (Seasonal variation - mg m⁻³)



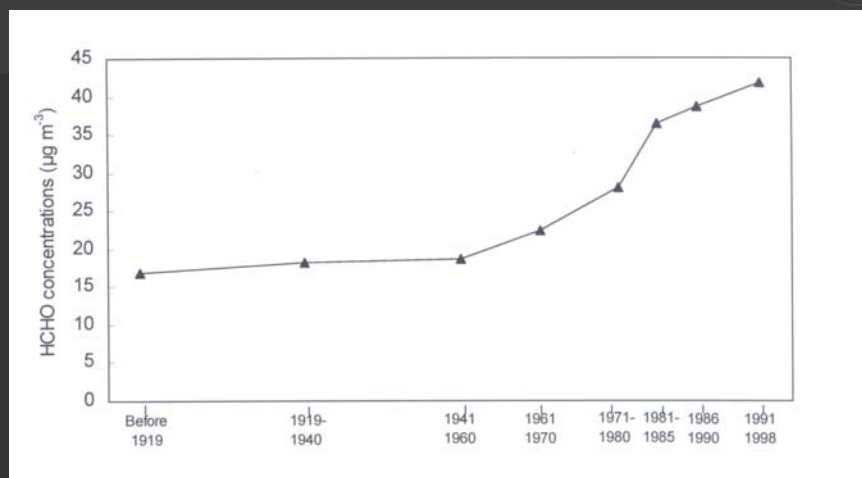
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Overview of main findings - CO

- The following factors were found to have a causal effect on CO levels:
 - season
 - cooking fuel
 - area type
 - heating systems and fuel
 - smoking
 - extract fan
 - household size
 - number of habitable rooms
 - use of gas cooker and portable heaters for heating

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Results - formaldehyde and age of house



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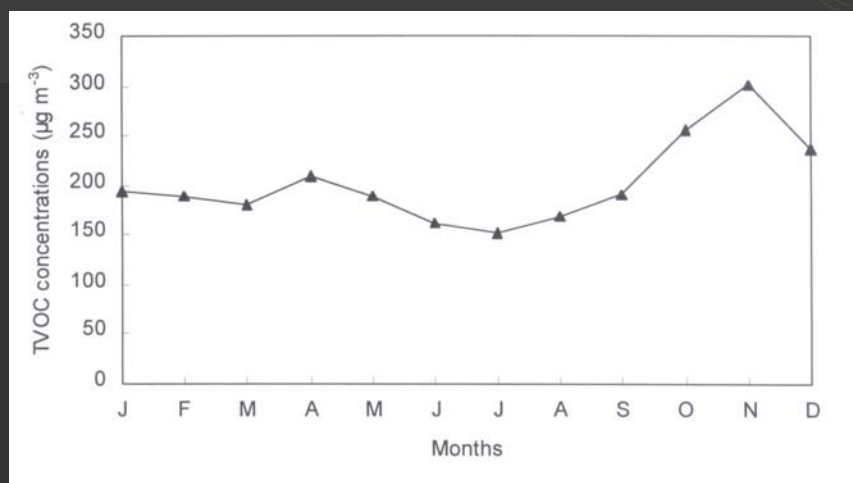
Overview of main findings - formaldehyde

- The following factors were found to have a causal effect on formaldehyde levels:

- house age
- particle board floor in the bedroom
- Other factors significantly associated because of their relationship with building age or particle board flooring were: month of sampling, dwelling type, number of bedrooms, the existence of a garage, damp problems.

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Results - TVOCs (monthly means)



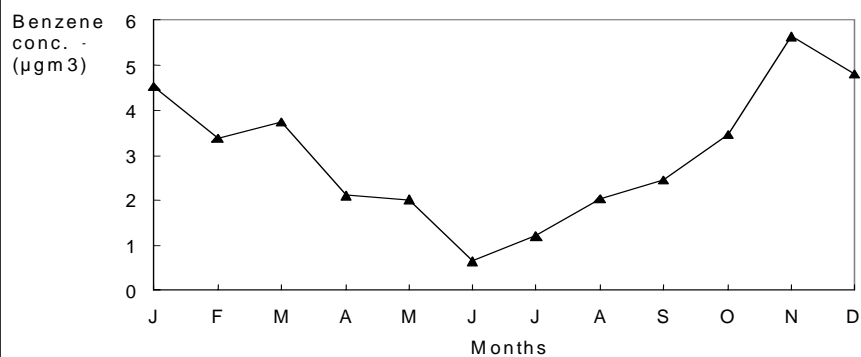
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Overview of main findings - TVOCs

- The following factors were found to have a causal effect on TVOC levels:
 - painting and decorating
 - season
 - house age
 - particleboard bedroom floor
- Other factors significantly associated because of age of house and particle board floors were; garage type, extract fan, occupant density and use of cleaning materials and toiletries.

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Benzene concentration in bedrooms by month of year



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Overview of main findings – individual VOCs

- The following factors were found to have a causal effect on benzene levels:
 - season
 - Integral garage with car
 - Door between living space and garage space
 - Occurrence of tobacco smoking
 - Location (higher in urban areas)
- Toluene, xylenes, limonene, undecane, Texanol and TXIB also subject of full data analysis

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IAQ survey recommendations on exposure

- avoid being in the same room as gas cooking activities, especially if a gas oven is in use, and/or ensure good extract ventilation close to gas cooking appliances,
- use low emission materials in the construction and furnishing of homes, and ensure good ventilation, especially during construction and the first year of occupancy,
- efforts to improve outdoor air will lead to improvements in the indoor air, especially in winter in urban areas, but will do little to affect the largest exposures indoors,
- the mere provision of ventilation devices has little effect, they need to be used,
- avoid exposure to tobacco smoke.

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IAQ and ventilation in homes built since 1995

- Range of home types in southern England
- 34 homes with mechanical extraction, 3 homes with PSV
- measure mean 2 week air change rate using PFT method
- measure IAQ parameters
- sample in winter (Jan-March 2002) and summer (2002)



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Measured ventilation and IAQ parameters

- inorganic gases; CO, NO₂
- organic compounds e.g benzene, toluene, formaldehyde
- non-biological particles; PM₁₀
- temperature and humidity
- Householders perception e.g. air quality, temperature, condensation
- Mean 2 week air exchange rate
- Air leakage at 50 Pa

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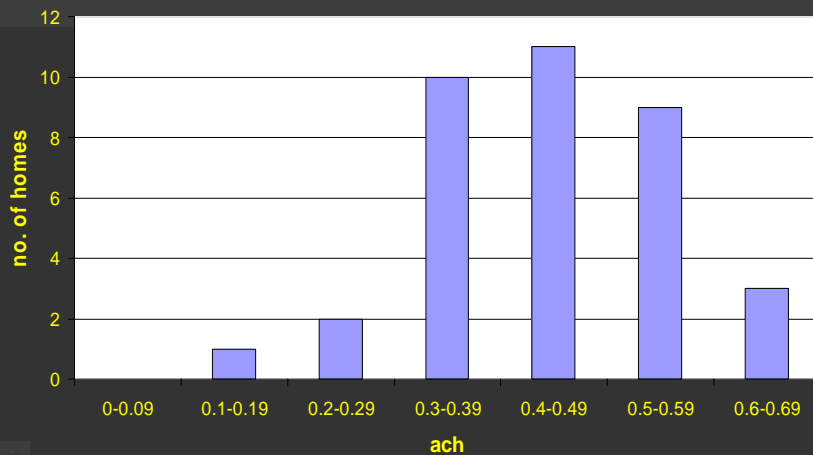
Measurement of mean ventilation rate

- release perfluorocarbon tracer into rooms from diffusion source at known rate
- measure concentration of PFT in each room using diffusive sampler
- measure volume of house and calculate mean rate of exchange with outdoor air



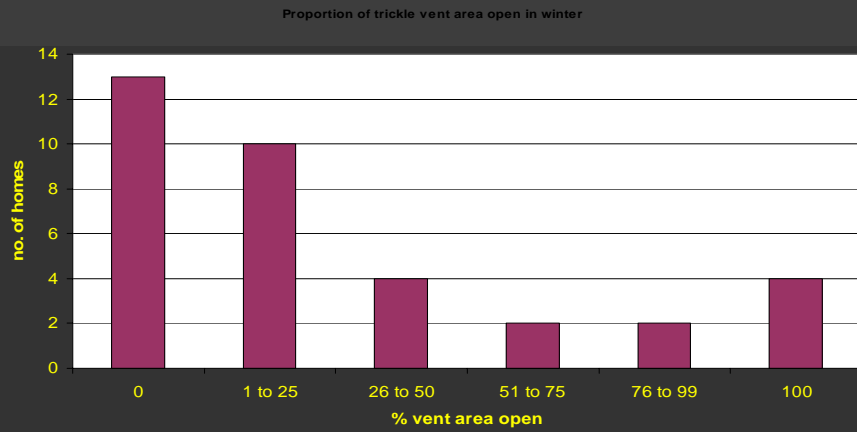
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Ventilation rate in winter



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Proportion of trickle vent area open in winter



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Window opening behaviour and ventilation rate in winter

Ventilation rate (ach)		
	Mean	N
Most or all of the times	0.59	3
Sometimes	0.43	14
Rarely or never	0.41	13

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Relation between ach and IAQ

Pollutant	ach ≤ 0.36		ach > 0.36, ≤ 0.49		ach > 0.49		F	p
	G Mean	N	G Mean	N	G Mean	N		
Living room CH ₃ CHO	20.1	10	12.9	10	9.7	10	4.9	<0.05
Living room TVOC	224	10	123	10	106	10	6.0	<0.01

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Conclusions

- Mean ventilation rate in winter in 37 homes built since 1995 only slightly below design value (0.5 ach).
- 38% of homes in winter were <0.4 ach.
- Trickle vents fully open in only 11% of homes (closed in 37%)
- Mean concentrations of CO, NO₂, formaldehyde and VOCs within typical range for UK homes; some guidelines exceeded in minority of homes
Highest NO₂ in homes with gas only cooking.
- VOC concentrations tend to be higher in homes with lowest ach (winter and summer)

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Site at Invergordon, Ross-shire, Scotland

- Two blocks of maisonettes comprising 24 properties
- on former gasworks site
- ground investigations identified contaminants in soils and groundwater including BTEX
- Detailed quantitative risk assessment identified inhalation of benzene in indoor air as a possible significant exposure pathway



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Aim of study

- To evaluate whether a significant pollutant pathway exists from the polluted ground to the indoor air

Issues

Ambient air quality standard of $16 \mu\text{g m}^{-3}$ with target of $5 \mu\text{g m}^{-3}$ (annual mean) by end 2010 and objective in Scotland of $3.25 \mu\text{g m}^{-3}$

No indoor air standard / objective

No data on typical concentrations of benzene in Scottish homes

Expect background benzene in ambient air and from indoor sources such as ETS and temporal variation in background as well as the amount of any ingress from the ground

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Design and sampling strategy

- Sample all 24 potentially impacted properties on two occasions; summer and winter.
- Sample each month in a sub-set of 6 properties over 12 months (Feb 2005 – Feb 2006).
- In parallel, sample 30 control properties (summer and winter) and a sub-set of 8 each month.
- Indoor measurements in living room and bedroom.
- Outdoor measurements in parallel.
- Use diffusive samplers to provide mean monthly concentrations.
- Measure ventilation rate in sub-set.
- Apply questionnaires to record household characteristics and sampling conditions (main and update).

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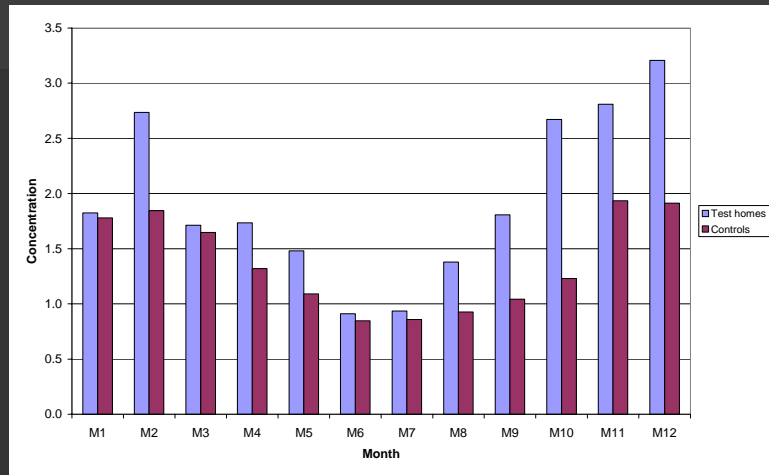
Sampling and analytical method for benzene

- Adsorbent tubes containing Carbograph ITD
- Samples placed in duplicate (10% of duplicates analysed)
- Analysis by ATD/GC/FID&MS
- UKAS accredited analytical method.



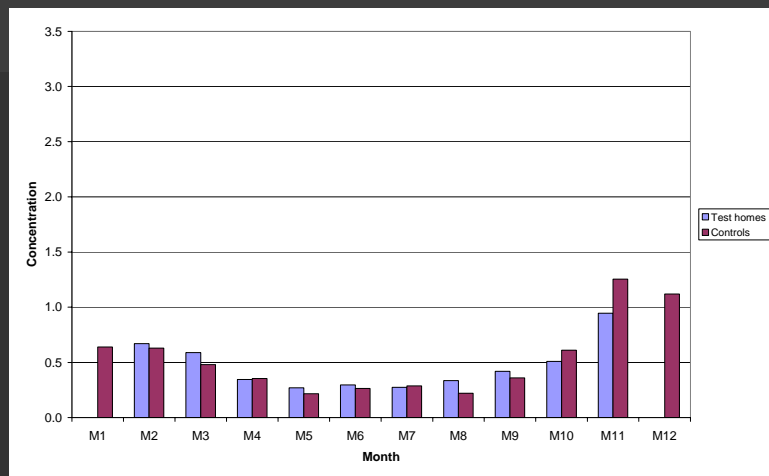
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Monthly mean benzene concentration indoors for test and control homes ($\mu\text{g m}^{-3}$)



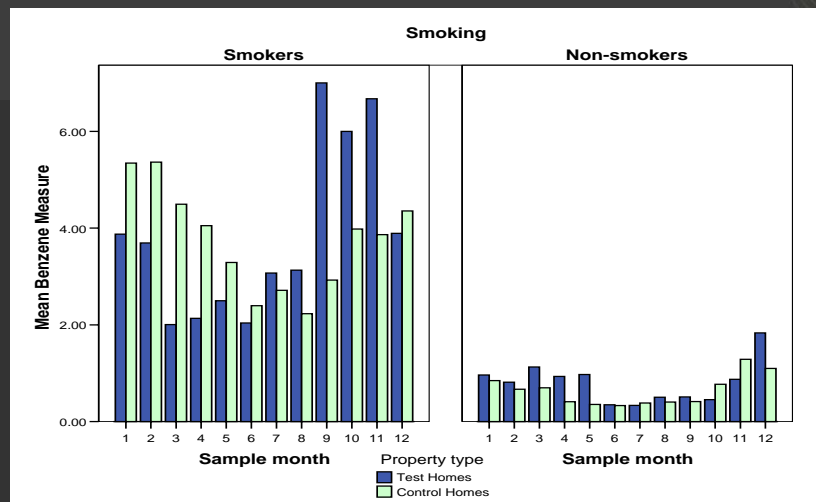
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Monthly mean benzene concentration outdoors for test and control homes ($\mu\text{g m}^{-3}$)



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Mean benzene concentration each month for smoking and non-smoking homes ($\mu\text{g m}^{-3}$)



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Conclusions

- Indoor concentrations exceeded outdoors and there was a seasonal variation
- Highest mean benzene concentrations were $5.8 \mu\text{g m}^{-3}$ for test homes and $5.4 \mu\text{g m}^{-3}$; these were in homes of smokers
- No significant difference between test and control properties
- Significant difference in mean benzene concentrations in homes with and without smokers
- Ingress of benzene vapour from the ground into the properties was not occurring at a sufficient rate to have a significant effect on benzene concentrations
- Concentrations recorded do not give rise to any cause for concern and are within the range likely to be experienced by the general population

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Pollutants/buildings for which low level of UK knowledge on indoor levels

- SVOCs,
 - MVOCs,
 - Organic / ozone and other reaction products
 - Particulates, including nano
 - biological particulates, except dust mites
-
- Offices
 - Schools
 - Other public buildings
 - Transport

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Expected and possible future controls/impacts

- Performance criteria for IAQ in Building Regulations in 2006
- Construction Products Directive
- Labelling schemes
- REACH
- Zero carbon buildings and MMC
- EU policy on indoor air quality

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Zero carbon housing

- 'within 10 years every new home will be zero carbon' (HM Treasury, Nov 2006)
- Expect implications for materials used, types of heating appliance, and ventilation
- Code for sustainable homes; Energy standards at levels 1 to 6 where 6 = completely zero carbon (all energy including electrical appliances)



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Conclusions

- Nationally representative surveys are challenging to undertake but provide a unique database to understand exposure to air pollutants and inform appropriate policies for their control
- Considerable data about some pollutants and some building types exists for England, but there are notable gaps
- Specific studies can target particular source types or population groups
- Control by measures such as Building Regs, product standards and outdoor air quality standards and changing markets such as the demand for zero carbon future and types of consumer product mean that regular surveys should be undertaken to assess what is a dynamic situation

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References for the BRE studies

- www.bre.co.uk

For references go to A-Z of services, 'indoor air quality' and open 'publications'

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