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IEH Institute of Environment and Health

3.3 Assessment of risk from inhalation exposure to benzene: A case study

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Presenter

Background and objectives

When assessing the possible risks to human health associated with contaminated land, one of the potential pathways of exposure to be considered is the release of chemical vapours that might be inhaled by people via ambient and indoor air. Concentrations in indoor air can be relatively high because of the occurrence of preferential pathways for soil gas movement into buildings and because of a build up of concentrations in the enclosed space (Crump, 2004).

A site identified as a priority within The Highland Council's Contaminated Land Inspection Strategy comprises a residential development in Invergordon, Ross-shire, constructed on land formerly occupied by a gas works. The residences situated on the former works consist of two blocks of maisonettes each consisting of 12 occupied dwellings. Desk and ground investigations undertaken by The Highland Council's Contaminated Land Team and their consultants identified a potentially significant pollutant link involving the inhalation of benzene by residents within the properties.

Subsequently, in September 2004, BRE undertook an initial phase of air quality monitoring that showed there to be no immediate risk to residents via the inhalation pathway. VOCs present in air drawn from boreholes situated in the garden areas to the front and rear of the buildings were also present in the indoor air, but as they are known to have other sources such as building materials and consumer products, including tobacco smoke, it was not possible to determine whether ingress from the ground accounted for some part of the concentration found in indoor air. It is known that the movement of organic vapours in the ground and their ingress into buildings is affected by weather, soil conditions and occupant behaviour. Further monitoring was therefore undertaken to provide information on the air quality over a 12-month period. In addition, parallel monitoring of benzene within a matched set of similar off-site properties within the Invergordon area was undertaken in order to provide a set of control results to compare with the test homes.

Study description

The stratified strategy involved a bi-annual and a monthly study. The bi-annual study aimed to determine the concentration of benzene in 24 homes near the contaminated site (test homes), and 30 control homes, once during the winter (February 2005) and once during the summer (August/September 2005). Sampling was achieved in 19 of the test homes during the winter and 20 in the summer. 30 control homes were sampled in the winter and 28 in the summer. The monthly study determined monthly variation in concentrations in six of the homes near the contaminated site and eight of the control homes over a 12-month period (February 2005 to February 2006).

At the start and end of each sampling event a record was made of air temperature, humidity and

weather. Also, questionnaires were completed for each sampling occasion to record characteristics of houses including activities such as smoking that may influence the indoor benzene concentration.

The measurement of benzene in air was undertaken using diffusive sorbent tubes packed with approximately 400 mg of Carbograph 1TD. A diffusive sampling exposure period of 4 weeks was used. This is because the concern for health in this context is the possible long-term exposure to benzene in air, and therefore 4 weeks provided an integration of the exposure, but also the long-term exposure period enabled an understanding of the temporal variation (including possible seasonal changes) in concentration to be assessed.

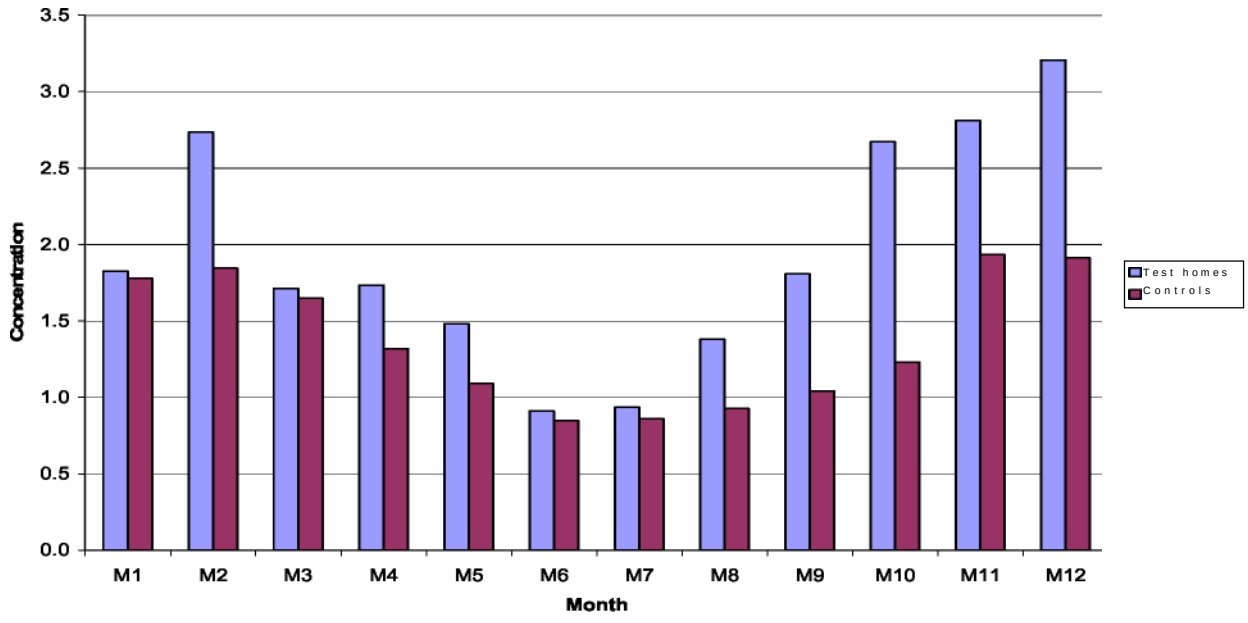
Samplers were placed in duplicate in the living room and main bedroom of homes and at outdoor sites by staff of The Highland Council following training given by BRE at the outset of the study. Exposed samplers and completed sampling forms were returned to BRE by post. All diffusive samplers were set out in duplicate and travel blanks were also provided with each batch of samples.

UKAS accredited analysis was undertaken at the BRE VOC analytical laboratory using thermal desorption/gas chromatography with flame ionisation and mass spectrometry detection (TD/GC/FID and MS). Quantification was by FID and the mass spectrum of the peak with the appropriate GC retention time for benzene was applied to check for the presence of interfering compounds. The results were subject to statistical analysis to investigate relationships between benzene concentrations and household characteristics and to compare the test and control homes. Also the data were evaluated by IEH to assess the risk to health of residents that could exist due to the benzene concentrations found.

Results

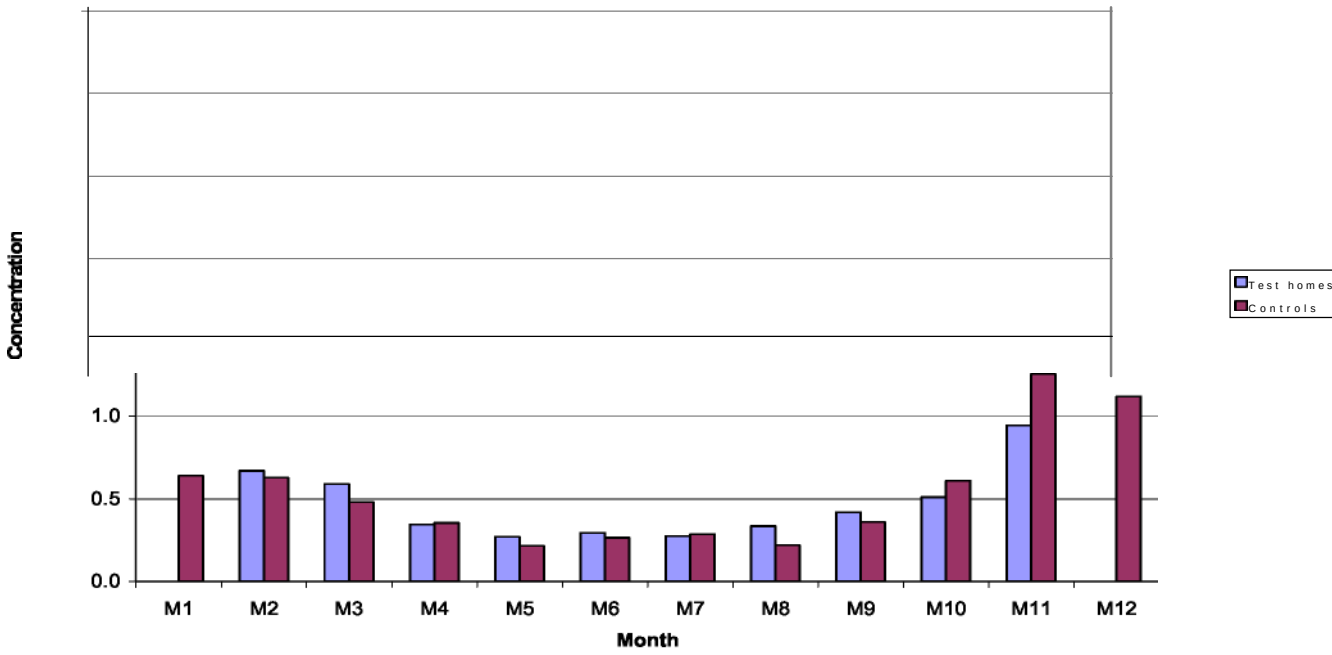
Figure 3.3.1 shows the monthly mean concentrations of benzene inside the test homes and controls, and Figure 3.3.2 the results for outdoors. The annual mean concentration of benzene for the test homes was 1.8 µg m^{-3} and for the control homes 1.4 µg m^{-3}. The mean concentration in outdoor air was 0.5 µg m^{-3} for the samplers placed outside the test homes and those placed outside control homes. A seasonal variation in benzene concentration was observed, with lower concentrations being recorded in summer months than in winter months.

Figure 3.3.1 Monthly arithmetic mean benzene concentrations for the test and control homes (µg m^{-3})



Source: BRE

Figure 3.3.2 Monthly arithmetic mean benzene concentrations recorded outside the test and control homes (µg m^{-3})



Source: BRE

Note: The test value for M1 is not available as placement of the sampling box was delayed, while for M12 the sampling box was stolen.

Differences in benzene concentration were observed between homes, with the highest annual mean concentration being recorded for one of the test homes (5.8 µg m^{-3}) and the second highest concentration being recorded by one of the control homes (5.4 µg m^{-3}). Both these homes were occupied by at least one smoker over the period of sampling.

The measured data do not follow the normal distribution, and statistical comparisons were made using non-parametric tests. Among the tests undertaken were a comparison of test and control homes and those with and without smokers. Tests show that there is a significant difference in the concentration of benzene measured between the homes of regular smokers and those of non-smokers. Higher levels of benzene were measured in homes with regular smokers than in homes without regular smokers. Analysis was then undertaken on the subset of homes containing regular smokers. Tests showed there to be no significant difference in the concentrations and distribution of benzene measured between test and control homes for this subset.

Further statistical analysis considered only results from homes which were not occupied by smokers. There was no significant difference in the concentration of benzene measured in control and test homes.

Discussion

Benzene is a genotoxic human carcinogen. As benzene is primarily found in the atmosphere, human exposure is mainly through inhalation. It is a product of combustion and a component of petroleum, and the main source of benzene in the outdoor air is emissions from traffic. The concentration of benzene indoors depends upon that entering from the outside by infiltration and ventilation plus contributions from any indoor sources. Tobacco smoke and the

permeation of air from integral garages are known sources of benzene indoors (Raw *et al.*, 2004; Mann *et al.*, 2001).

The National Air Quality Strategy for England, Scotland, Wales and Northern Ireland was reviewed in 2000 and this set an ambient (outdoor) air quality objective for benzene of 16 µg m^{-3} as a running annual average mean concentration to be achieved by December 2003. In 2003 in Scotland additional regulations set a second air objective of 5 µg m^{-3} or less, when expressed as an annual mean, to be achieved by 31 December 2010 in accordance with an EC Directive (96/62/EC). Local regulation in Scotland further set an objective of 3.25 µg m^{-3} to be achieved by 31 December 2010.

There is no UK air quality standard for indoor air in homes. In 2004 an expert committee of the Department of Health recommended guidelines for the concentration of some indoor air pollutants in homes, and for benzene it recommended a guideline value of 5 µg m^{-3} as an annual average concentration. In the present study no readings above 16 µg m^{-3} were recorded. An annual mean concentration of greater than 5 µg m^{-3} was recorded in two test homes and one control home. One further control home recorded an annual mean concentration of >3.25 µg m^{-3} (3.6 µg m^{-3}), this being the result of two measurements in the home in February 2005 and August/September 2005.

Conclusions

The study successfully undertook the measurement of air quality in the indoor and outdoor air of homes constructed on land formerly occupied by a gas works, and at a control site, over a 12-month period. The control homes were shown to be similar to the study homes with regard to a number of house characteristics that may affect the concentration of air pollutants in homes.

Differences in benzene concentration between homes were found on statistical analysis to be explained by whether or not there was an occupant who smoked in the home. For homes without smokers, no significant difference was found in the concentration of benzene measured between the test and control homes. This shows that any ingress of benzene from the ground into the properties is not occurring at a rate sufficient to have a significant effect on the benzene concentration in the homes.

The assessment of the risk to health from exposure of occupants of the homes to benzene undertaken by IEH concluded that the concentrations recorded during the study do not give rise to any cause for concern. The values recorded are within the range considered likely to be experienced by the general population without measurable ill-effect.

Acknowledgements

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