

# UK PERSPECTIVE ON INDOOR AIR

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## ABSTRACT

In comparison to outdoor air issues, indoor air quality has received relatively scant attention from researchers and policy makers. This is for a variety of reasons including, for example, the lack of political will to interfere with people's domestic environment and the rather limited understanding of the scale and importance of the impacts of indoor air quality on health. That is not to say, however, that there is no interest in the subject or that a significant amount of research has not been conducted. For example, for many years there has been a series of international meetings on the topic – such as the 'Indoor Air' and 'Healthy Buildings' conference series – and some countries are becoming increasingly active in this area. In Europe there has been, since the late 1980s, a 'collaborative action' on indoor air quality. Certainly it is now widely accepted that exposure to a number of important pollutants is driven by exposure in the home, and that some particularly vulnerable groups, such as the sick, the very young and the very old, spend a very large proportion of their time indoors.

In the UK, interest in the issue of indoor air quality began in earnest with the publication in 1991 of the House of Commons Select Committee Sixth Report on '*Indoor Pollution*', which made a number of important recommendations that were followed up by government. One of the consequences of this report was the initiation of an intensive programme of monitoring in a selection of English housing, together with some experimental work investigating emissions of substances from materials and appliances. Measurements made were then assessed for their potential impacts on health through an in-depth toxicological and epidemiological review process. The pollutants assessed included nitrogen dioxide, formaldehyde, volatile organic compounds, house dust mites, carbon monoxide and moulds. An important recommendation of the 1991 report, that is only now being addressed in earnest, concerned the formulation of indoor air quality guidelines.

This paper will present some of the findings of the toxicological/epidemiological reviews on key indoor pollutants and will explain how the recommendation of the Select Committee to "...develop guidelines and codes of practice for indoor air quality in buildings which specifically identify exposure limits for an extended list of pollutants..." is now being progressed in the UK. Some other relevant initiatives will also be outlined.

# **INDOOR AIR QUALITY, AN E.U. PERSPECTIVE THE “EnVIE” PROJECT**

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## **ABSTRACT**

Modern European citizens can spend in excess of 90 % of their time in indoor environments. Up to now national and European air quality policies have devoted most of their efforts towards the limitation of outdoor environmental concentrations for some specific pollutants resulting from industrial activities and automobile traffic. It is now recognized that indoor exposures to air pollution must be given a better attention in policy making at European level. One of the first objectives is to increase the understanding of health impacts of indoor air quality through the co-ordination of European research activities within the context of the 6th Environmental Action Programme, the development of a Community Environment and Health strategy, the development of European public health policy and the new Community strategy on health and safety at work. It is therefore the objective of the EnVIE project selected by the European Commission DG Research, to increase the understanding of health impacts of indoor air quality. It will especially focus on the assessment of policy relevance of research into the health effects of isolated agents and mixtures, and will consider the implications for thresholds and safety margins for the general population and for people at work. It will address in particular how indoor air quality contributes to the observed rise in asthma and respiratory allergy as well as in other acute and chronic health impacts. To respond to the objectives, EnVIE has identified three major and complementary issues as key questions regarding indoor air and estimated manageable in terms of scientific and technical proximity: Exposure, Health effects and Spaces characterisation and sources. Since the aim of EnVIE is to aggregate building blocks, interfacing sciences and policy making, EnVIE will specifically consider the issue of integration and policy interface. It will also give a large attention to the dissemination in particular through the organisation of EnVIE conferences and reports. EnVIE is designed for three years duration starting from early 2004. It is based on a core group of participants from the European collaborative action “urban air, indoor environment and human exposure” together with JRC and WHO. The consortium has 19 participants from 14 different countries, including eastern countries, all participants being selected from their scientific excellence and for their ability to disseminate and interface the outcome of the project with policy making.

# COMPARATIVE SURVEY OF INDOOR AND AMBIENT AIR POLLUTION

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## ABSTRACT

Traffic-related VOC's may be present in indoor air either due to infiltration from traffic flow or due to emissions of the same VOC's from specific indoor sources. Important industrial emissions in the immediate vicinity of dwellings may have a similar effect on indoor pollution as traffic. The main aim of this comparative survey is to evaluate the impact of front door traffic flow to the indoor pollution levels. The selected VOC's were benzene, toluene, ethylbenzene and xylenes which comprise 25-30 % of the total NMVOC emissions by gasoline motor vehicles. Butyl acetate was selected as marker pollutant for local industrial emissions. Since these VOC's are not exclusively associated to traffic or industrial sources, MTBE was in addition selected. This compound will act as an indicator for traffic pollution and as an overall measure for infiltrating ambient air to the indoor environment.

During two measurement campaigns in 2001, weekly average diffusive sampler results were collected. Participating dwellings have been selected on the basis of traffic flow intensity and were grouped into four categories : from nearly no front door traffic flow (< 50 vehicles per day) up to worst case locations with 25000 vehicles per day. All dwellings were more or less evenly distributed over the area of the city of Mechelen (75000 inhabitants and 1157 inhabitants/km<sup>2</sup>). At each location, the indoor (living room and main bedroom), façade (front door) and garden measurements were performed simultaneously, resulting in about 1200 individual concentration levels for the global set of 7 pollutants.

The most striking observation is that for all VOC's the mean indoor concentrations are most frequently between 1.5 and 2.5 times the values measured at the corresponding outdoor sites. Even ratio's up to 10 prevail. On average between 32 and 55 % of the VOC concentrations found indoors originated from indoor sources or, expressed slightly different, did not infiltrate from outdoor to indoors. Further calculations show that the difference between indoor and outdoor VOC concentrations will increase towards 2010 by 9-14 % as compared to 2001. This is a result of the ambitious VOC emission reduction scenario's for the transport and industrial sector (a decrease of 42 % over 10 years) and the lack of policy measures in the field of indoor air. The implementation of legislative measures for indoor air pollution could change this trend and is therefore in the future a requirement for the successful abatement of health effects caused by air pollution.

## CHEMICALS IN HOUSE DUST

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### ABSTRACT

Fine particles are a medium to enrich and to keep organic compounds of low volatility and aerosols because of their efficient sorption processes. Therefore, the fine particles of house dust generally mirror the chemical history of the indoor environment. For this reason house dust is frequently used as a medium to evaluate the occurrence of chemicals in indoor environments. In many cases the aim of the evaluation is to find out whether or not chemicals contained in dust represent a health hazard.

Sampling house dust is very easy, but the analytical results should be interpreted very carefully due to various pitfalls. Major difficulties may arise from the variable composition of the dust matrix, the age of the sampled dust, particle size distribution and inhomogeneity of the sample, the influence of the sampling process and very near sources of contaminants as well as the lack of sufficient SRM for all contaminants of interest.

Studies on heavy metals in house dust, with a focus on lead, have been conducted for many years. In areas with heavy traffic and especially with heavy industries median values of more than 300 mg lead/kg house dust were assessed in the past. Biomonitoring data showed a significant correlation between the content of lead in house dust and the blood lead level. However, new data show a decrease of lead in house dust. Representative and most recent evaluations in Germany reveal a median value of 45 mg/kg.

The assessment of organic compounds in house dust is often carried out to prove applications of these chemicals in the present or in the past. Biozides, PAH, plasticizers, flame retardants and other organic compounds of very low volatility have been analyzed in various studies and on special occasions. Especially DEHP is ubiquitously spread with median values of about 0.5 g/kg house dust. Biocides and BaP can be found in the low mg/kg range. However, correlation of organic compounds in house dust with biomonitoring data has not been found up to now.

Despite these facts house dust is a very useful indicator to confirm the presence of chemical components in indoor environments. Results of repeated representative studies can show trends. In the case of harmful chemicals increasing values may serve as a strong argument for intervention (e.g. restrictions on chemicals) or as a proof of a successful intervention in the past if the trend declines.

## ASSESSING EXPOSURE TO VOCS AND PARTICULATES

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### ABSTRACT

Of necessity, our current strategy for estimating the exposure of a population to air pollutants is based upon centralised measurements of pollutant concentration, for example at city centre or urban background monitoring stations. More recently it has become accepted that, even if such measurements are representative of a sub-set of the population, the vast majority will receive something other than this “standard” dose by virtue of variations in their daily patterns of activity. In order to assess the highest exposures received by a significant proportion of the population, and so have the means to protect such “critical groups”, it is necessary to take a probabilistic approach to possible exposure levels. An alternative strategy is therefore required, in which the probability of individuals within a population receiving a particular exposure must be considered. We have explored this “microenvironment” approach to exposure modelling, both for “normal” healthy adults and for a range of groups more susceptible to the adverse effects of air pollution, including schoolchildren, pensioners and sufferers from lung and heart disease.

Even within a single microenvironment, apparent exposures determined through the use of fixed-point monitors may differ from actual exposures measured using personal samplers. In the indoor environment this phenomenon is most pronounced for particles, with the existence of a personal cloud of particles being evident. We have explored the extent and composition of this cloud in an effort to assess its origins. For example it has been possible to distinguish between resuspended particles originating from the floor and those generated directly from the person or clothing. An understanding of the spatial and temporal distribution of pollutants within a room, or series of rooms, is also crucial in carrying out representative sampling. Another area in which pronounced concentration gradients are seen is at the roadside, with high concentrations falling rapidly within the space of a few metres distance from the kerb. The use of techniques such as single particle mass spectrometry is beginning to shed light on the relative contributions of different sources to particle concentration at a given location, and so inform sampling strategy.

# **THE DEVELOPMENT OF INDOOR AIR MEASUREMENT TECHNOLOGY**

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## **ABSTRACT**

Air is a ubiquitous source of human exposure to pollutants. Outdoor point sources, such as smoke stacks have been regulated in the US for many years. Fugitive emissions and non-point sources are more difficult to identify and measure and hence regulations have been slower in coming. Indoor air has been of interest and regulated in the workplace for years, for occupational exposure. Only in the past few years, with the advent of “sick building syndrome”, has it become evident that pollutants are also present at significant quantities in some workplaces without obvious chemical exposure.

Homes and office buildings may also have significant concentrations of irritating or hazardous pollutants. These pollutants can be introduced into the air through home building materials, such as insulation, glues, and paints. New furniture and carpet can also contribute to the vapors in the air. Second-hand smoke is increasingly recognized as a problem for children. Radon is a pollutant permeating through cracks in the foundation in certain parts of the US, that has become more commonly recognized as testing is required at the time of a property transfer. Leaking underground storage tanks, although the focus of vigorous cleanup efforts in recent years, can contaminate underground wells, used as a source of drinking water or pollute buildings directly with vapors.

As general indoor air monitoring becomes more common, the list of compounds of interest and analysis methodology can be developed. The logical source for starting information is derived from previously developed methodology for outdoor air. Recent advances in outdoor air toxics technology will be described and extrapolated to indoor air measurement. The effect of varying humidity and compensation methods will be discussed. Detection limit requirements for indoor air compared with outdoor air will be evaluated. The use of diffusive sampling for indoor air will be compared with pumped sampling for outdoor air. Remaining work to generate a rugged methodology will be summarized.

# **RADON IN THE ENVIRONMENT**

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## **ABSTRACT**

Radon is a radioactive gas arising from the uranium decay chain. Because there are traces of uranium in all rocks and soils, radon comes out of the soil everywhere, all the time. Radon levels in houses vary widely from area to area depending on local geology and the permeability of the ground. However, the relationship with geology is complex, and average indoor radon levels can vary across a single geological unit. Even in one street on a uniform geology, indoor radon levels vary widely depending on house characteristics and the living habits of the occupants.

In a typical house, a couple of cubic metres of soil air enter each hour. The air comes in through holes and gaps such as those around service entry points or between floorboards, and is sucked in by an underpressure caused by rising warm indoor air. The highest levels of radon are generally found in the small hours of the morning and in the middle of winter - at the coldest times, when buildings are tightly closed.

Once radon is in a house, it undergoes radioactive decay and turns from a gas into atoms of solids, some of which emit alpha particles. When we inhale these solid decay products they deposit on the lining of the lungs. The alpha particles they emit damage the sensitive cells which line the airways, and can cause lung cancer. On average, the radiation dose and risk of cancer from radon is about a thousand times greater than that from the nuclear power industry. Many governments and international bodies have therefore recommended that radon exposures in houses should be limited. In the UK there is an Action Level for radon, set at 200 becquerels per cubic metre, ten times the average indoor level.

The National Radiological Protection Board has made around 450,000 radon measurements in UK houses, as part of government programmes. The measurements are made using small passive detectors sent by post. Where the radon concentration is above the Action Level, remedial measures can typically reduce the level by a factor of ten. Building regulations have been altered in radon-prone parts of the country to prevent houses being constructed with radon problems.

# PROTOCOLS FOR INDOOR AIR MEASUREMENTS

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## ABSTRACT

Indoor air quality (IAQ) can have an important impact on the health and well being of building occupants. The vast majority of people's time is spent in buildings and therefore the quality of the indoor air is a major determiner of the population's exposure to air pollutants (1). Provision of adequate IAQ depends on the provision of sufficient 'fresh' air to dilute and remove contaminants. These include the products of metabolism of occupants and the gases, vapours and particles emitted into the indoor air through emission from furnishings and materials, the use of consumer products and release by biological sources such as fungi, bacteria and mites (2). Currently the UK Department of Health is reviewing the need for IAQ standards or guidelines for key indoor air pollutants.

Indoor air measurements may be undertaken for a number of possible objectives including;

- the investigation of a cause of complaint by occupants perhaps of odour, irritation or other health effect (2),
- an assessment to demonstrate that the performance of a building is satisfactory in providing acceptable indoor air quality (3),
- the study of people's exposure to pollutants (4),
- contaminated land risk assessments (5).

It is important to clearly define these objectives before devising an appropriate strategy to achieve them within the available resource. There are a number of factors to consider at this stage and this should include the selection of appropriate methods of measurement for the range of pollutants of interest.

This paper outlines the on-going work within the British standards Institute (BSI), the European Standards organisation (CEN) and the International Standards Organisation (ISO) to develop standards that provide guidance on defining a strategy for indoor air investigations and procedures for the measurement of specific pollutants. It also refers to guidance produced by other organisations, including BRE (6). Studies are described as examples of indoor air investigations where judgements were required to define an optimum sampling strategy and to select the most appropriate sampling and analytical methods.

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## MONITORING ABOVE AND BELOW THE WAVES

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### ABSTRACT

This talk describes two programmes of monitoring air quality, both related to the offshore industry, both presenting interesting challenges in terms of analytical methodology and of interpretation of the results. On the other hand, the pollutants of interest and their sources are different.

Deep sea divers remain in a closed environment at pressures of up to 20 bar for 3 - 4 weeks at a time, the two factors accentuating the need for a very clean breathable atmosphere - not air, but a mixture of helium and oxygen. The major pollutants are hydrocarbon vapours, especially the aromatics, traceable to leakages and spills of crude and processed oil. Sampling and sample handling is probably the biggest problem, while the analysis itself can be handled by TD-GC-MS. Assessment of the quality of the diving atmosphere involves considerations of the toxicities and the concentrations of many different compounds. The performance of the methodology and examples of the high quality of the typical modern diving environment will be presented.

Assessing the air quality at a large harbour presents different problems. We are not sure which pollutant presents the greatest hazard, so  $\text{NO}_2$ ,  $\text{CO}$ , VOCs (especially benzene) and  $\text{PM}_{10}$  are all being looked at. So also is  $\text{SO}_2$ , a relic of the past as far as urban air pollution is concerned, but one which has been suggested as being still with us around the harbour, arising from the heavy fuel oils being burned by ships. The task of the current survey is to assess the levels of these different pollutants, to attempt to identify sources, and to relate the levels found around the harbour at Aberdeen with those measured in the centre of the city, only a couple of hundred metres away. Is the harbour the source of the urban pollution or a clean sanctuary within a polluted urban environment? Here also the performance of the methodology will be presented, along with a rationale for the design of the survey and choice of methods.

# THE PROBLEMS WITH BUILDING MATERIALS

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## ABSTRACT

Synthetic materials are complex systems consisting of e.g. thermoplastic polymers compounded with process aids, such as stabilizers, viscosity modifiers and cosolvents. These components can be volatile as such, or they may contain solvents or volatile impurities, which may give rise to emissions and cannot be foreseen by the building material manufacturer. Thermoset materials are produced from resins consisting of monomers, oligomers or other low molecular weight reactive organic compounds through curing processes such as crosslinking, vulcanization or oxidation. Most materials require additives such as plasticizers, antioxidants, surface treating agents and colorants to attain the technical properties and to be attractive and to have a long performance life. Even natural materials such as native, solid wood contain extractives, which are volatile giving wood its typical odour.

Polymeric materials are "chemically" living and are in the long run and sometimes already during the manufacturing process affected by oxidation and degradation reactions giving rise to emissions. These emissions are in many cases odorous and irritative.

Material emissions are prevalent especially in new and renovated spaces. When the emissions are high enough, they give rise to indoor concentrations causing irritation and health problems. Very often excessive emissions cause strong odour. In order to promote the development of less emitting, healthier materials, e.g. Germany, Denmark/Norway and Finland have established labelling or classification systems based on somewhat different criteria. In Germany there is a labelling system, AgBB, under development, which is based on the European guideline published as ECA Report 18.

Common to these labelling systems is that the emissions are measured in controlled emission test chambers according to specified sampling and test specimen preparation methods given in CEN and ISO, which defines the procedure for TVOC and VOC determination in the range covered by Tenax TA. Below this range are the aldehydes, especially formaldehyde and other low boiling aldehydes, and ketones. Above are the semiVOCs including e.g. pesticides. The outlying compounds need to be analysed with separate techniques.

Odour is a vital character of material. This caused by the emissions and it is this part the consumers use in everyday life in evaluating the quality of the materials and indoor air. So far there is, however, not a European consensus of a method for determination and evaluation of the odour. In Nordtest a method exists and is used in Scandinavian odour testing.

The labelling systems have contributed enormously to the indoor air quality properties of materials. Only in a few cases today new materials or buildings are subject for complaints. In Finland these cases are today mainly concerned with the emission of an ester used as viscosity modifier in non-classified materials. This ester has in clinical tests shown to cause new asthma.

Oxidation and especially degradation reactions are in the severe cases triggering irritative emissions, which today are the major causes for material originated health problems. These problems can be avoided by careful design, building practise and maintenance of the buildings. When something goes wrong, the source identification and right reparation methods are one of the challenges of today in providing a continuously comfortable and healthy living and working environment.

# ARE WE MEASURING THE RIGHT INDOOR SPECIES?

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## ABSTRACT

Common organic compounds in indoor air (OCiAs) emitted from building materials, except for a few biologically reactive compounds (e.g. formaldehyde, acrolein), are unlikely to provoke eye or airway complaints, common in offices, at typical indoor concentrations (1). However, certain building materials, some after long time, emit (secondary) OCiAs with low odour thresholds, that may effect the immediately perceived air quality (odour intensity) (2;3). This may result in odour annoyance, often mistaken as airway irritation, which depends on a number of personally related factors (4). For certain building materials (e.g. textile carpets) O<sub>3</sub> (ozone) may produce or remove odorous OCiAs thus affecting the perceived air quality (5). Identification of odorous OCiAs is difficult, but labelling schemes may to some extent diminish the odour impact (3).

OCiAs are chemically non-reactive or reactive (e.g. with O<sub>3</sub> and the hydroxyl radical), like terpenes. The latter are common OCiAs emitted from wood, plant, and fruit based materials (e.g. limonene). In addition, terpenes are common fragrances used in many consumer products. O<sub>3</sub> oxidizes terpenes under typical indoor conditions producing a number of oxygenated products (e.g. (6)). It is inferred from a mouse bioassay (7) and a human exposure study (8) that oxidized terpenes produce eye/airway irritants unidentifiable by conventional analyses.

The degradation products of Tenax TA, a common adsorbent, have been studied by sampling oxidants followed by thermal desorption and gas chromatography (9). NO<sub>2</sub> and the hydroxyl radical both produce 2,6-diphenyl-p-benzoquinone (DPQ), while specific degradation products were identified for O<sub>3</sub> and NO<sub>2</sub>, only. Tenax TA exposed to O<sub>3</sub>-limonene products results in 2,6-diphenyl-p-hydroquinone (DPQH); however, DPQ and DPQH cannot be differentiated analytically. It may be possible to measure the impact of oxidized limonene products, if the DPQ formation is NO<sub>2</sub> dose-dependent, thus allowing for correction.

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# **MEASUREMENT OF ATMOSPHERIC PARTICULATES IN AMBIENT AIR USING SURFACE ACOUSTIC WAVE DEVICES**

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## **ABSTRACT**

It is a statutory duty of district and city councils in England to carry out an assessment of air quality in their area, Environment Act (1995) Part IV and guidance from the Department for the Environment, Food and Rural Affairs (DEFRA). These duties require local authorities to review and assess air quality to identify local air quality management strategies (LAQM) and meet air quality objectives. The EU has set limit values for carbon monoxide, sulphur dioxide, and lead for 2005 and nitrogen dioxide and benzene for 2010.

The Government has adopted two air quality objectives for particulates ( $PM_{10}$ ) that are equivalent to the EU stage 1 limit in the first Air Quality Daughter Directive. The data is obtained using a gravimetric sampler. Indicative limits for  $PM_{10}$  to be achieved by 2010 is an annual mean of  $20 \mu\text{g}/\text{m}^3$  and a 24 hour mean of  $50 \mu\text{g}/\text{m}^3$  to be exceeded on no more than seven days per year. However, in order to study the origin and composition and hazards presented by particulate a more details on their composition and the particle size distribution is needed. There is a clear need for real time measurements with high spatial resolution to elucidate the sources and chemistry of particulates and the processes involved in their formation and fate.

This paper presents the development and evaluation of an electrostatic precipitator surface acoustic wave (EP-SAW) system for real time monitoring of particulate matter. Particles are separated into size ranges by a cyclone collector and charged using a  $Am^{241}$  source and subsequently collected directly onto the metallised propagation path of the SAW device functioning as charged collector. Mass loading of the piezoelectric sensor device due to particle precipitation is then recorded as the output from the induced phase shift of the SAW resonator.

# **SICK BUILDING SYNDROME**

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## **ABSTRACT**

In general the houses we live in today are very good compared to only 100 years ago.

Today we normally have electricity, central heating, cold and warm water, water toiles, ventilation, Air condition and a lot of electrical equipment's which makes daily life comfortable. But still there are a lot of houses in which the occupants have complaints on the indoor environment. The first publication on bad indoor environment is in the The Holy Bible, Leviticus 14:33. Since then a lot of investigations of the indoor environment has been published. In 1983 WHO published a definition of the "Sick-Building-Syndrome". This definition is unspecific and can not be used for medical diagnosis of "Sick-Building-Syndrome".

Today it is estimated that about 30% of all buildings are affected by Sick Building Problems.

In the indoor environment one can measure a lot of chemical, biological and physical parameters, like for instance VOC, humidity (water), particles, mould, bacteria, ventilation, noise, light, temperature etc. None of these measurements can be correlated to a specific health effect for the diagnosis of "Sick-Building-Syndrome". By questionnaires and statistical evaluation, buildings with problems can be identified and both residents and the building can be investigated. From the obtained results from questionnaires, correlation's to health effects like asthma, hyper sensitivity including MCS (Multiple Chemical Sensitivity) and correlation to the occurrence of some chemical, biological and physical parameters has been reported.

There is one compound that seems to have an essential impact on several other parameters. This compound is water. Water has an impact on emissions from building materials, chemical reactions in building materials, adsorption onto particles, growing of mould and bacteria. High humidity (e.g. high water concentration in indoor Air) correlates to asthma and hyper sensitivity. High humidity also correlates to poor ventilation efficiencies.

If we could control the amount of water in indoor Air and in building constructions and materials, a lot of the sick building problems could probably be solved.

To do this we have to learn to measure water in a correct way and to correctly interpret the obtain results from the water measurement.

# VENTILATION AND INDOOR AIR QUALITY

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## ABSTRACT

Indoor air pollutants occur because of pollutants entering the building from the outdoor air or ground, and because of emission from sources within the building, such as materials, furnishings, combustion appliances and use of consumer products (Crump, 1997).

The TEAM study in the USA in the 1980s was the first major study to draw attention to the importance of the indoor environment and people's activities for determining population exposure to a range of air pollutants (Wallace, 1993). In 1997 the WHO reviewed knowledge of the exposure to air pollutants in indoor environments and stated 'The quality of air is the most essential determinant of the quality of life. As people in temperate climates spend on average 80-90% of their lives indoors, this refers mainly to the quality of indoor air' (WHO, 1997).

There are two main approaches to controlling levels of indoor air pollution: to dilute the level of pollution by ventilation and to minimise the source. Ventilation above a certain level may have unacceptable costs in terms of energy for moving, heating and cooling the air, and may cause occupant discomfort because of draughts. It also requires air of good quality to dilute the pollutants generated in the indoor environment. Source control can be through the careful selection of products that release only low amounts of pollutants or by somehow isolating or modifying the source. Local controlled ventilation, as used for cooker hoods, can also be used to reduce the spread of pollutants within a building arising from a particular source. As dwellings become more airtight, the relative importance of internal air pollution sources for indoor air quality (IAQ), as compared with ingress of pollutants from outdoors, becomes greater.

Amongst a range of studies on ventilation of buildings, BRE has undertaken a study of ventilation and indoor air quality in 37 occupied homes built since 1995. The primary objective of this project was to determine whether the guidance in the 1995 revision of the Building Regulations Approved Document Part F is effective at providing adequate ventilation and air quality in homes. Approved Document F (ADF) was last revised in 1995 and is currently being reviewed by BRE.

This paper discusses some of the most common methods used to determine the ventilation rate in buildings, with particular reference to the 37 occupied homes study as an example, in which a passive perfluorocarbon tracer (PFT) technique was used. Seasonal effects on ventilation and indoor air quality arising from a number of parameters, such as window opening, heating, temperature, outdoor pollution levels and occupant behaviour have also been investigated in this study along with measurements of airtightness and infiltration of the house using fan pressurisation.

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# THERMAL DESORPTION TECHNIQUES FOR INDOOR MEASUREMENTS

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## ABSTRACT

Thermal desorption (TD) is a readily automated gas extraction technology based on standard gas chromatography parameters and providing an efficient, high-sensitivity alternative to conventional solvent extraction for volatile and semi-volatile organics. It is applied in single stage form to whole-air samples (canisters, bags, air streams) or in two stage form to organic analytes collected on sorbent tubes. (Semi-)volatiles can also be desorbed directly from materials. Ultimately, the organic analytes are retained on a small sorbent focusing trap which is subsequently heated rapidly, in a reverse flow of inert gas. Under the influence of heat and gas flow, analytes 'thermally desorb' from the trap into the gas stream and are transferred to the analyser as a small (100-200 $\mu$ l), discreet and concentrated volume of vapour. Overall concentration enhancement factors as high as  $10^4$  (single stage) or  $10^6$  (two stage) can be obtained using thermal desorption thus allowing conventional laboratory gas chromatography (GC) or GC-mass spectrometry (GC-MS) technology and/or alternative real-time vapour detectors (enose sensor arrays, process MS, etc) to measure compounds that were originally at ppb or ppt concentrations.

VOC monitoring applications for indoor air relate to both toxicity (risk of adverse health effects in humans or animals) and odour/nuisance. Since implementation of the new Integrated Pollution Prevention and Control (IPPC) regulations (Council Directive 96/61/EC on IPPC), odour is now considered a harmful pollutant in the sense that it causes 'offence to the senses of human beings'<sup>1</sup>. Given the sensitivity of the human nose to some classes of organic compound at sub-ppb levels – particularly oxygenated compounds and those containing nitrogen or sulphur – thermal desorption is invariably required as part of any analytical procedure for monitoring odour – i.e. TD-GC-MS/(-enose) methods provide the only viable analytical option to olfactometry

There are four major roles for thermal desorption relating to indoor air monitoring. These are:

1. Profiling organic vapours in indoor air (odours and toxic compounds),
2. Testing VOC and semi-volatile organic emissions from construction materials and other consumer products (identifying the sources of indoor air pollution) under simulated real-world conditions
3. Determining the volatile content of indoor materials (not the same as (2))
4. Monitoring ventilation using perfluorocarbon and other tracer gases

Though inherently simple, many factors contribute to the performance and efficiency of the TD process which in turn determines the ultimate sensitivity and reliability of a TD-based analytical method. This paper describes the primary sampling and instrumental criteria likely to affect the performance of thermal desorption procedures for typical indoor air monitoring applications including the measurement of odorous and reactive species. Examples are presented from each of the four main indoor air applications and a novel approach to method/data validation via repeat analysis is described.

New technology enhancements which allow the fixing of retention times of thermally desorbed compounds (with or without additional confirmatory MS data) are also presented. These allow confident measurement of trace-level, odorous or toxic, target analytes in worst-case sample matrices – i.e. amongst complex mixtures of higher concentration organics.

A review of relevant regulatory developments and the level of monitoring required is also presented.

### References:

1. Best available techniques for assessment and control of odour, UK Env. Agency Rpt. Ref. P4-079/2/TR, ISBN 1 857059 352 07/02

# **STANDARDS, CALIBRATION AND TRACEABILITY**

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## **ABSTRACT**

Traceable calibration is a fundamental requirement in measurement methods, which underpins Quality Assurance and Quality Control and enables comparability between measurements. The increasing use of sorbent tubes for indoor air and workplace monitoring, and in particular the application of BS EN ISO 16017 'Indoor, ambient and workplace air – Sampling and analysis of volatile organic compounds by sorbent tube, thermal desorption, capillary gas chromatography' places requirements for calibration. In order to obtain traceable measurements not only must the analysis stage be calibrated but also the sampling stage, and this implies the use of traceable uptake rates, and knowledge of the sorbent tube performance characteristics.

This talk will present a summary of work that is being carried out within the DTI's Valid Analytical Measurement programme to support indoor air, workplace and ambient air measurements. It will cover a recent study on indoor air monitoring, the development and availability of calibration standards covering a wide range of species, and advances in techniques for the calibration and validation of sorbent-based monitors, including the determination of uptake rates. In particular a facility will be described which can be used for the accurate assessment of sorbent tube performance, for quantifying uptake rates and to expose tubes to provide calibration and QA/QC artefacts.

# **QUALITY ASSURANCE/QUALITY CONTROL (QA/QC) OF INDOOR AIR MONITORING**

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## **ABSTRACT**

During the performance of an indoor air survey comprising a ‘full-time’ one-year monitoring programme of pollutants consisting of consecutive 24-hour air samplings and subsequent sample analysis, a comprehensive QA/QC programme has been implemented. Elements of this programme were:

- method validation, including determination of safe-sampling volume, desorption efficiencies and measurement uncertainties
- the analysis of duplicate samples by one or more laboratories
- the analysis of control samples and certified reference materials
- the organization of a (small-scale) proficiency test
- the performance of internal and external audits.

In this presentation, an overview of the setup of this programme and some results (effects) of the implementation of this QA/QC programme will be presented.

# **FINGERPRINTING ORGANIC INDOOR AIR POLLUTANTS**

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## **ABSTRACT**

A wide and varied range of organic air pollutants can be encountered in the indoor air environment at concentrations down to sub ppb level. The air pollutants in question can comprise permanent gases, volatile organic compounds, semi-volatile organic compounds and particulates/aerosols. Of these different physical forms, volatile organic compounds are probably most common. The specific distribution of organic air pollutants reflects closely the particular indoor atmosphere and can provide a “fingerprint” of this localized environment. Such environmental “fingerprints” have been used by M-Scan in forensic investigations to associate a suspect with a particular crime scene.

The detailed analysis of indoor air pollutants is amenable to established methods, particularly GC-MS, but in view of the typically low concentrations some prior enrichment is invariably needed. This can involve active pumping of known volumes of air through adsorbents such as Tenax or passive sampling onto activated charcoal or better still fabrics in the room in question.

This novel analytical approach will be illustrated by reference to particular case studies and the sources of indoor air pollutants discussed and compared (building materials, plastics, food, cooking odours, decorating and cleaning products, deodorants, toiletries, perfumes, house plants, outdoor air pollutants, even body odour).

## CONTAMINATED LAND, IMPACT ON INDOOR AIR - MEASURING THE SOURCE TERM IN LANDFILL GAS

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### ABSTRACT

A mixture of methane and carbon dioxide is the primary aerial emission from landfilled waste. However, a large number of trace components are also swept out with this bulk gas. Together these traces make up only 1% of the gas by volume but potentially have a disproportionately higher impact on odour or health. The composition of this complex source term is needed as input to risk assessment models that estimate off-site impacts.

Over 550 individual compounds have been reported in landfill gas and so a method of prioritising those of most significance has been developed. Each substance is assigned a significance score based on health or odour related impact and the average concentration reported in landfill gas. A suite of four monitoring methods has been selected to cover those substances making the greatest contribution to the significance score (see Table below).

<b>Tenax TA / Unicarb, Dual solid sorbent in Sulphinert coated tube; ATD-GC-MS</b>			<b>Activated charcoal sorbent; ICP-MS/AAS</b>
Chloroethane	1,1-dichloroethene	1,3-butadiene	Arsenic (as As)
Chloroethene	1,2-dichloroethene	Furan (1,4-epoxy-1,3-butadiene)	<b>DNPH Reactive silica sorbent; HPLC</b>
Benzene	Carbon disulphide **	1-pentene *	Methanal (formaldehyde)
2-butoxy ethanol	Methanethiol *	1-butanethiol *	Ethanal (acetaldehyde) *
1,1-dichloroethane	Butyric acid *	Dimethyl sulphide *	<b>Hand-held gas analyser</b>
Trichloroethene	Ethyl butyrate *	Ethanethiol *	Hydrogen sulphide **
Tetrachloromethane	1-propanethiol *	Dimethyl disulphide *	

Odour impact; \*\* odour and health impact; all others significant for potential health impact

Sampling raw landfill gas onto sorption tubes presents a number of challenges. The pump has to be safe for use close flammable gas, usable in a remote location and able to give metered flow against the vacuum in the gas line. Raw landfill gas is a warm, moisture-saturated mixture and so avoiding condensation during sampling and interference of water during analysis is crucial to success. Competition from non-priority compounds reduces the usable capacity of the sorption tubes significantly but still provides superior detection limits and substance recovery figures compared with Tedlar Bag sampling.

# MEASUREMENT OF ENVIRONMENTAL TOBACCO SMOKE

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## ABSTRACT

Environmental Tobacco Smoke (ETS) is a growing concern due to the accumulating evidence for its adverse health effects on non-smokers and increasingly, restrictions are being placed on smokers to limit exposures. ETS is complex mixture of aerosols (or suspended particles) and gases, and is composed of over 4000 components. Clearly it is not possible to measure all constituents of ETS, so, in order to determine the contribution of ETS to indoor pollution in environmental studies, marker substances are required. These are used as surrogates for ETS exposure which can be related to the amount of smoking taking place and the ventilation conditions in the areas monitored. While this seems a straightforward task, given the large numbers of components to choose from, it has in fact proved very difficult to find reliable markers. A number of approaches to measuring ETS contamination are described in this paper including respirable suspended particles, ETS specific particles, nicotine and cotinine. A case study of the use of these techniques in a study of UK pubs and bars is presented that has used area sampling for ETS related particles and nicotine. The results of this study highlight the importance of suitable marker selection.