AIR MOVEMENT & VENTILATION CONTROL WITHIN BUILDINGS

12th AIVC Conference, Ottawa, Canada
24 - 27 September, 1991

POSTER 4

The use of test chambers for characterizing the emissions of volatile organic compounds from indoor building materials

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Synopsis:

Increasing interest is attributed to the problem of the accumulation of organic vapours emitted from indoor building materials due to an effective insulation of buildings with low ventilation rates. A measurement technique for determining emission rates using a 1 m^3 laminar flow test chamber is described. The aim of this activity is to:

- get compound-specific data on the emissions of various indoor building materials,
- provide emission data for the development and verification of models used to predict indoor concentrations and
- determine the effect of environmental variables as temperature, humidity or air velocity on emission rates.

The work of a COST 613 working group leading to a guideline for measurements using test chambers [1] was an important step to internationally harmonize analysis and data evaluation methods.

List of abbreviations

EMPA	Swiss Federal Laboratories for Materials Testing and Research
EPA	US Environmental Protection agency
VOC	Volatile Organic Compounds
GC/MS	Gas chromatography combined with mass spectrometry
GC/FID	Gas chromatography with flame ionization detector
COST 613	European Concerted Action "Indoor Air Quality and its Impact on Man".

1. Introduction

Public interest in indoor air problems has increased considerably during the last years. Due to better insulation of rooms for reasons of energy saving with correspondingly low air change rates in unventilated rooms and the use of a variety of artificial indoor materials there is a certain risk for higher concentrations of indoor air pollutants.

Measurements of indoor air in fact often shows significantly higher concentrations of air pollutants compared to ambient air [2,3,4]. Often the reason for this increased concentrations are building materials [5,6].

Today there is still a lack of knowledge of type and time dependence of VOC emissions from building materials.

2. Measurements in test chambers

The characterisation of emissions from building materials in real rooms is extremely difficult due to the immense number of parameters influencing VOC concentrations (sources like building materials, furnishing, paints, indoor activities; sinks like walls, plants, carpets; fluctuating room temperature and humidity, air change rate etc.). In order to obtain well defined and reproducible information about VOC emissions from a specific building material, measurements in test chambers with exactly controllable conditions are necessary.

With the support of the Swiss Federal Office for Energy the EMPA started a project aiming at the development of a method for the characterisation of VOC emissions from building materials using test chambers.

International harmonisation of measurement methods is highly desirable in order to reach a good comparability of data obtained by different laboratories. An important step towards this goal was the participation in the work of a COST 613 working group leading to a guideline for measurement of emission factors from indoor materials using test chambers [1], a guideline which made use of a preceeding work in the EPA [7].

3. Design of the test chamber

The test chamber used in this project has a volume of 1 m^3. All parts coming into contact with the air to be measured are of stainless steel. Temperature, humidity and air change rate are controlled. The fresh air is carefully purified from VOC to a low ppb-level. An independent control of the wall temperature allows to avoid cold spots in the system, minimizing thus wall absorption effects. With the internal air recirculation system a known laminar air velocity in the test chamber can be maintained and simultaneously the temperature can be controlled. Fig. 1 gives a schematic view of the test chamber design.

4. Sample collection and analysis

Normally air samples are taken at the exhaust of the chamber. An exactly known volume of air (typically 500 ml) is drawn through adsorption tubes filled with Tenax. Immediately after sampling the tubes are tightly sealed and transferred into the analytical laboratory. The analysis is done after thermal desorption by GC/MS technique for compound identification and by GC/FID technique for quantitative analysis of time series. A more detailed description of these procedures can be found in the COST guideline [1].

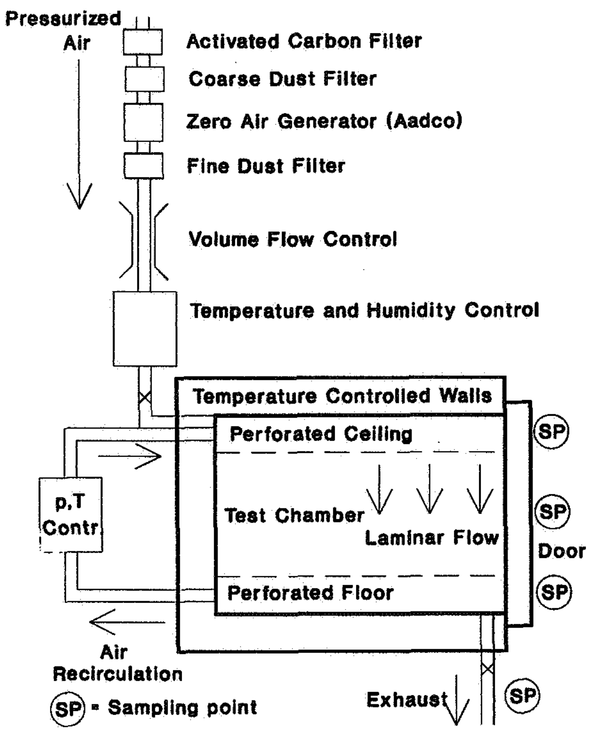

Fig.1: Set-up of test chamber

5. Experimental parameters

The first step in designing an experiment for chamber tests of building materials is to determine the test objectives. For example an architect might be interested in emissions from a variety of materials to be used under a given set of conditions for a specific building. In this case, the experiment would be designed to deal with many materials with one set of environmental conditions. The same may happen, if data for a source emission inventory are to be collected. A manufacturer might want to know the emission characte ristics of a specific product under both normal and extreme conditions. Researchers interested in the interactions among variables would use a more complex design involving ranges of several variables.

Six parameters are generally considered to be critical:

- Temperature (affecting vapour pressures, diffusion coefficients and desorption rates)
- Humidity
- Air exchange rate (defined as mass flow rate of clean air to the chamber divided by the chamber volume)
- Air velocity near the surface of the materials being tested
- Product loading (defined as the ratio of test specimen area to the chamber volume)
- Product age/product history (influencing emission rates very strongly)

For routine testing of indoor materials the following test conditions are recommended:

Temperature:	23^0 C
Relative humidity	45 %
Air exchange rate	0.5 and/or 1 h^{-1}

Concerning product loading and air velocity realistic values should be chosen.

6. Data analysis

The aim of the chamber measurements is to identify the predominant or otherwise interesting components emitted from the investigated materials and to establish quantitative emission rates. These are normally expressed in mass · area^{-1} · time^{-1} (e.g. mg m^{-2} h^{-1}).

6.1. Constant emission rates

For materials with a relatively constant emission rate over the test period the chamber will reach and maintain a constant equilibrium value. The emission factor (ignoring sinks) will then be:

$$E = Qc/A = Nc/L$$

E	=	Emission factor (mg m^{-2} h^{-1})
Q	=	Flow through chamber (m^3 h^{-1})
c	=	Chamber concentration (mg m^{-3})
A	=	Sample area (m^2)
V	=	Chamber volume (m^3)
N	=	Q/V Chamber air exchange rate (h^{-1})
L	=	A/V Chamber loading (m^2 m^{-3})

6.2. Decreasing emission rates

The simplest model (ignoring sinks) assumes that the chamber is an ideally stirred tank reactor and that the change in emission rate can be approximated by a first order decay [7].

$$E = E_0 e^{-kt}$$

leading to:

$$c = L E_0 (e^{-kt} - e^{-Nt})/(N - k)$$

Values of E_0 and k can be obtained from concentration vs. time data series by a non-linear regression.

6.3. General empirical model

The following double-exponential equation for describing the time dependence of VOC concentrations has been successfully used by Colombo et al. [8].

$$c = a(1 - e^{-k_1 t}) - b(1 - e^{-k_2 t})$$

where c and t still denote concentration and time. a and b (mg m^3) are the linear parameters and k_1 and k_2 (h^{-1}) the rate parameters of the equation. This model may equally well fit to data which, starting from zero, increase with time, eventually reaching an asymptotic steady equilibrium value, or to data which pass through a maximum and then decline to zero or to some intermediate equilibrium value.

As an example for this type of data evaluation Figure 2 shows the time dependent concentration of m/p-xylene emitted from kork plates.

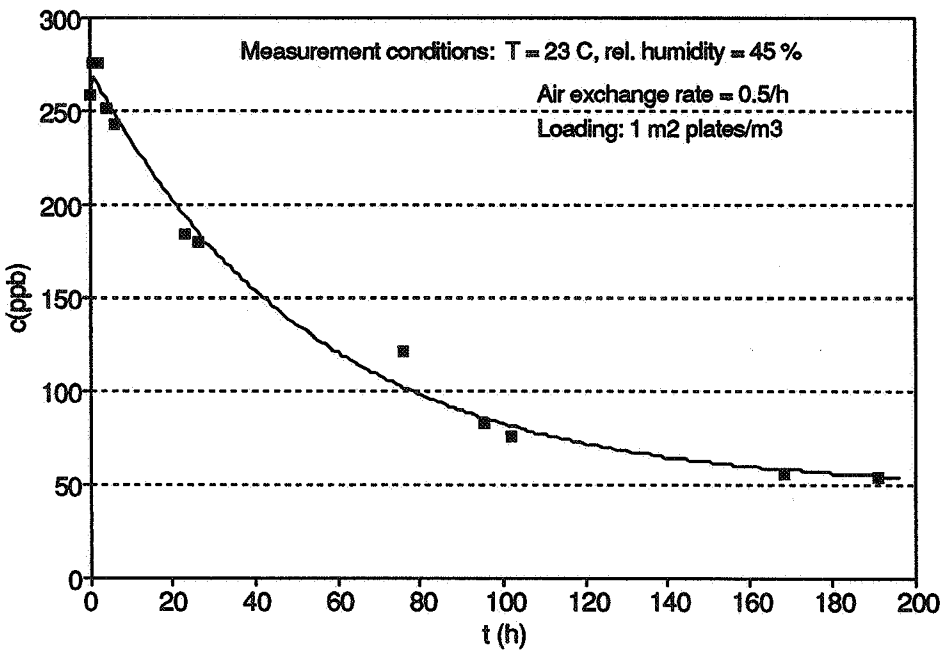

Fig.2: Emissions of m/p-xylene from kork-plates

measured concentrations

calculated concentrations using the best fit of the general empirical model: $c = 273\ (1 - e^{-6.14\ t}) - 224\ (1 - e^{-0.019\ t})$

7. Conclusions and recommendations

Emission factors obtained from concentration measurements in test chambers may represent a useful tool for builders, architects or designers of ventilation systems not only to choose the adequate material but also to estimate or model VOC concentrations to be expected in real rooms.

However it is important that laboratories working in this field harmonize their measuring procedures in order to supply comparable and consistent data, which in a later stage could be collected in a data base.

The guideline prepared by the COST 613 working group [1] will hopefully help to reach this goal.

8. Acknowledgements

We gratefully acknowledge the financial supporting by the Swiss Federal Office for Energy for this project.

The authors would like to thank the chairman M. De Bortoli and the members of the COST 613 WG 8 for numerous valuable discussions.

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