

TRACER GAS MEASUREMENTS IN APARTMENT BUILDINGS

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SUMMARY

The development of a tracer gas method for measurements of airchange rates including passive sampling is briefly described. This method has the potential to be used in a large scale at a reasonable cost. It is also suitable for use of many tracer gasses to be analysed in the same sample.

The results from recent calibration measurements show that improvements of the analytical system is necessary before final evaluation of e.g. systematical measurement errors can take place.

Results from continuous tracer gas measurements with the constant concentration method for one unoccupied apartment with mechanical exhaust ventilation show very small differences in airchange rate due to fluctuations in wind speed and wind direction.

1 INTRODUCTION

Tracer gas measurements of airchange rates in dwellings is very time-consuming and expensive. There is a need for simple measurements that can be used for larger scale investigations. There is also a need for measurements that can be used in occupied dwellings during longer periods of time and for methods that can give information of multi-cell airflows between e.g. rooms or apartments.

One method using different perfluorocarbon tracers and the constant emission principle with diffusive sampling seems to fulfil these needs. The method was firstly developed by Russel Dietz at Brookhaven National Laboratory, USA, and has been found to work well by comparative measurements with other tracer gas methods, Dietz et al (1986). This principle has been used in a joint project between EHUB and the Analytical Chemistry Department at the University of Stockholm to develop a similar Swedish method for use in apartment buildings. Equipment development is also in progress in the United Kingdom, Littler et al (1985).

If complete mixing of the tracer gas and equilibrium conditions are assumed, the airchange rate is inversely proportional to the gas concentration. Systematical errors resulting from the constant emission principle have recently been investigated in laboratory at the Swedish Institute for Building Research. These results will be published during 1987.

2 MEASUREMENT SYSTEM FOR DIFFUSIVE SAMPLING

The diffusive sampling technique is one way to measure concentrations of different compounds in air. This technique is based on Fick's first law of diffusion, Kristensson (1984):

$$N = -DA \, dc/dx$$

where

N = diffusive transport rate, moles/s
D = diffusion coefficient in air, cm²/s
A = diffusion path cross-section area, cm²
c = concentration, moles/cm³
x = distance, cm

Under steady state conditions and integration over the length of the diffusion zone, L (cm), the amount of pollutant collected, M (moles), during the time t (s) is described by:

$$M = DA/L * ct$$

The following assumptions are made:

1. Concentration at adsorbent surface is zero (zero sink).
2. Concentration at sampler face represents the ambient concentration.
3. The diffusion coefficient is independent of concentration and matrix effects.
4. Steady state diffusion applies.

The expression DA/L is called the Uptake factor and is ideally a constant for the used system configuration, which is true for adsorbents with sufficient strength. The Uptake factor for our system has been found to vary with concentration and exposure time. A calibration curve for the Uptake factor as a function of time and concentration has been established to account for these effects.

The chemical analysis is performed in laboratory by gas chromatography and electron capture detection. Automatic thermal desorption of the sampling tubes is used by means of a Perkin-Elmer ATD-50 system.

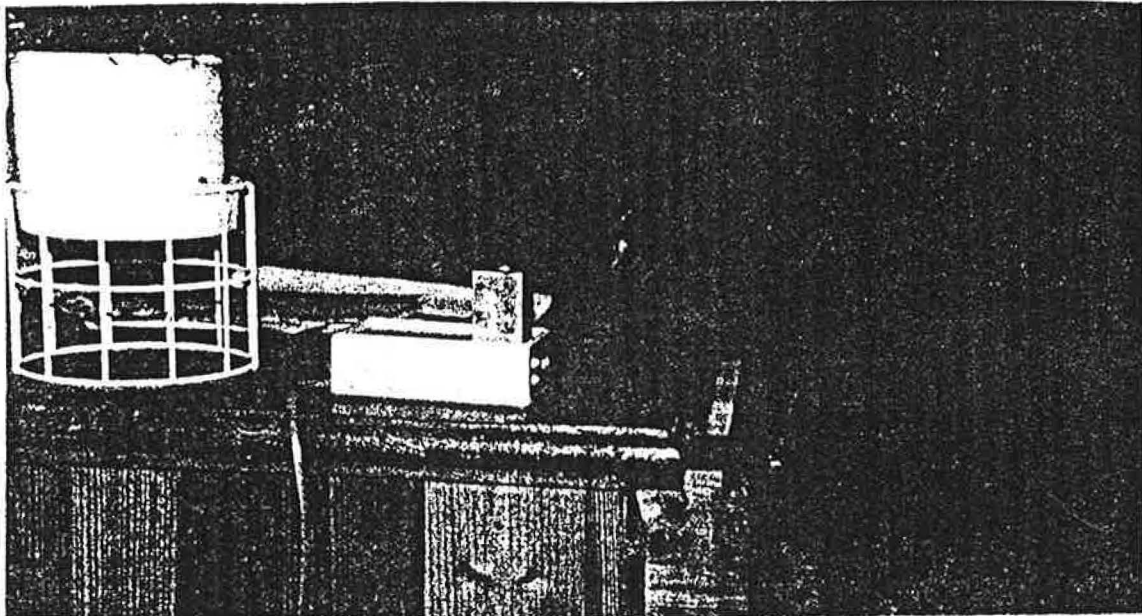


Figure 2.b. Tracer thermostat in field use.

3 MEASUREMENT RESULTS

3.1 Calibration measurements

A great number of laboratory tests has to be performed for every change in the analytical system configuration. This is done at the chemical laboratory in an environment with known concentration of tracer gas. The purpose is to calibrate the system and to make sure that the right peaks in the chromatograms are found without disturbing peaks of other compounds. With the present configuration, these measurements indicate an accuracy of $\pm 6\%$ for this part of the analysis.

Table 3.1.a. Uptake factors from recent calibration measurements for PMCH. The KTH-box is a 1.4 m³ box with known airflows and complete mixing, while SIB and Konsolen are apartments. Thus the standard deviation for the apartments also account for concentration variations in the different rooms.

Test	Exposure time min	Conc. ppb	Uptake factor ng/ppm min	St.dev. %	N
KTH-box	7182	0.18	1.02	16	5
SIB 1	5640	0.0089	2.46	26	10
SIB 2	5965	0.0089	1.50	15	7
SIB 3	7306	0.0082	5.01	54	7
Konsolen	12945	0.0022	1.94	18	5

Calibration measurements to find uptake factors were also carried out, see Table 3.1.a. Previously, this was done by comparison of pumped and diffusive sampling at every

measurement. To avoid this procedure, uptake factors are determined in laboratory boxes with controlled airflows. Different combinations of concentrations and exposure times have to be tested. The table shows the first round of results, which are a little discouraging and have resulted in modifications in the analytical system.

3.2 Continuous measurements

Comparative measurements with continuous constant concentration tracer gas technique has been performed in one unoccupied apartment. The results are shown in Figure 3.2.a. The house has mechanical exhaust ventilation and very good airtightness. The ventilation system creates a negative pressure inside in the order of 15 Pa. The apartment walls are exposed to SE and SW.

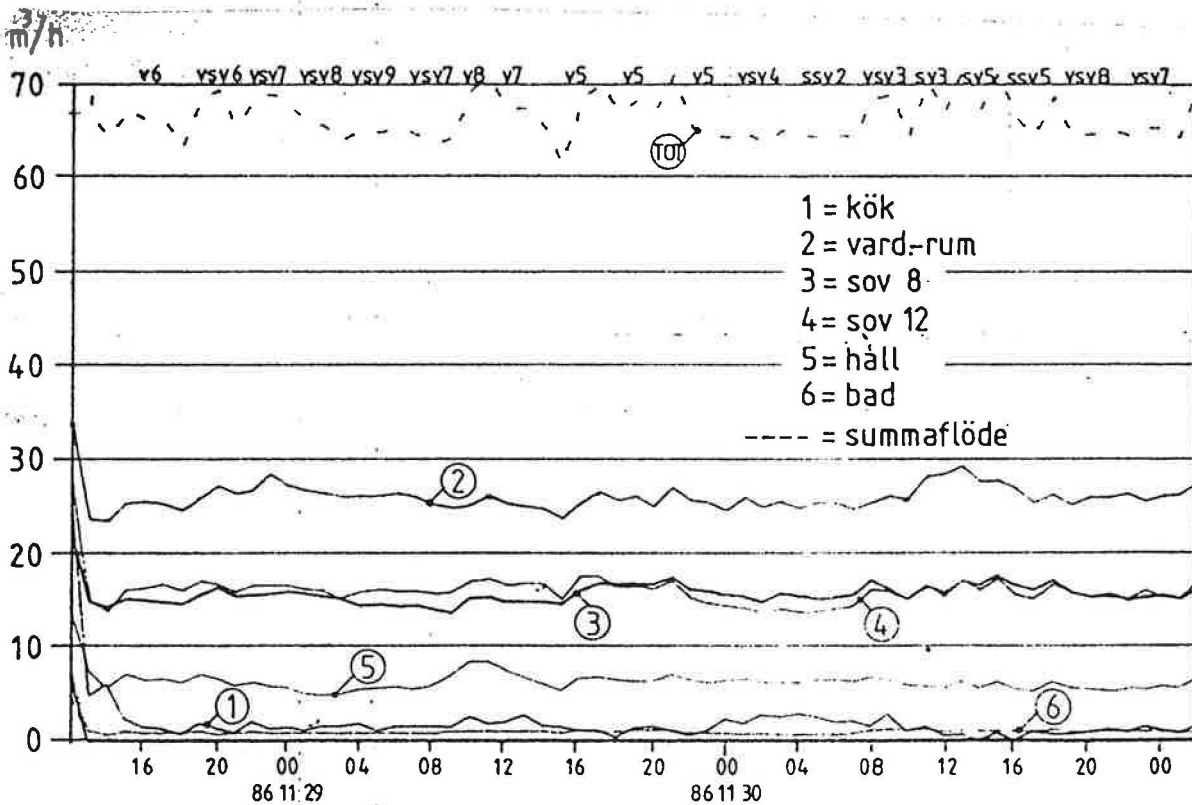


Figure 3.2.a. Results of continuous tracer gas measurements in "Konsolen" 861128-861201. The letters and numbers at the top of the graph indicate wind directions and wind speeds from the Bromma climate station.

So far, the major part of the work has concentrated on finding a reliable combination of adsorbent materials, chromatograph columns and calibration methods. This is a very difficult task because of the extremely low concentrations used, 0.01-1 ppb. It requires extensive testing in both laboratory and field. Field tests are needed in all stages of development because system configurations that work well in the laboratory environment has sometimes been found to fail when used in field applications. At the moment, the system is about to be modified once again because of unexpected errors in field measurements. The target accuracy of the laboratory analysis is to be within 10 % reproducibility.

The sampling tubes consists of 90 mm long steel cylinders with adsorbent material, see Figure 2.a. The diffusion length is well defined in one end. The cylinders are capped in both ends when not in use. It is essential that the end caps seal well to avoid contamination during transport. The standard caps was found to be too leaky and were replaced with Swagelok caps. During measurement the cap at the diffusion end is replaced by a mesh cap.

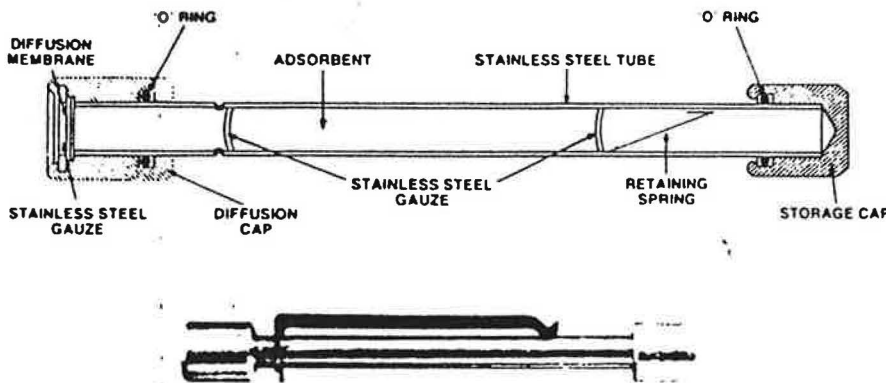


Figure 2.a Diffusion sampling tube.

The adsorbent used so far is Porapak Q, which is a relatively weak polymer adsorbent. This is to be replaced by a carbon material, which is a stronger adsorbent.

Liquid tracer sources are kept in small glass bottles with a teflon/silicone membrane. They are thermostatted at 60 °C to ensure stable and constant emission rates, see Figure 2.b. There exist a number of perfluorocarbon tracers that can be used. So far tests have been made with three different tracers: PMCH, PDCB and PDCH. Of these, PDCB seems to be the most difficult to use accurately because of its low boiling point, 45 °C. Most tests have been performed with PMCH at an emission rate of about 150 ng/min.

The tracer gas method with passive sampling seems promising, but improvements in the chemical analysis are still needed before it can be used in a larger scale. Good results can be achieved with the current configuration, but too many measurement points give results with no meaning. With the modifications that currently are taking place, the number of failing points should be minimized.

The continuous tracer gas measurements in the Konsolen apartment show very small dependence of wind fluctuations on the airchange rate.

The development of the chemical analytical system has been performed by Jan Kristensson at the Analytical Chemistry Department, University of Stockholm. This is the most critical part of the system and his work is gratefully acknowledged. The advice given by Dr. Russel Dietz, Brookhaven National Laboratory is also very much appreciated. The department of Building Services Engineering at the Royal Institute of Technology is gratefully acknowledged for the use of the box with controlled airflows.

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