CHARACTERIZATION OF THE FIELD AND LABORATORY EMISSION CELL - FLEC: IMPACT OF AIR VELOCITIES ON VOC EMISSION RATES

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ABSTRACT

The Field and Laboratory Emission Cell (FLEC) is a tool for non-destructive emission testing of materials with even surfaces. Measurement of air velocities inside the cell showed an inhomogenous flow field with a high-velocity area around the inlet axis and an area of comparatively low air velocities perpendicular to the inlet axis. These results suggest that punctual emission sources may lead to different VOC-concentrations depending on the position of the source. To confirm this assumption a test plate with constant emission sources was designed and the concentration deviations at different source locations inside the FLEC were determined. Depending on the distance between the source and the FLEC-center deviations of 10 - 35 % have been measured . The deviations were found to be almost independent of the total air flow through the cell.

INTRODUCTION

The Field and Laboratory Emission Cell (FLEC) is a device for non-destructive emission testing of homogenous surfaces. In contrast to other small emission test chambers the surface of the test specimen becomes the bottom part of the FLEC. A detailed description of the cell is presented in (1,2,3).

Compared to a well mixed emission test chamber the air velocity at the sample surface is difficult to determine. Theoretical calculations of the flow field in the FLEC led to the assumption that high air velocities should be measuarable at the inlet slit directly at the inlet axis, and an area of comparatively low air velocities is expected perpendicular to the inlet axis.

In contrast to well-mixed emission test chambers, where a recommended air velocity of about 30 cm/s for standardized emission testing had been introduced (4), neither recommendations nor experimental data exist for the FLEC. Experimental determination of the air velocity inside the cell confirmed the theoretical prediction and showed an inhomogenous flow field, where significantly higher air velocities were measured at the inlet axis (5). Depending on the angle, air velocities in a range from 0.3 to 0.9 cm/s were measured for a total flow of 250 ml/min. There is an area of low air velocities located perpendicular to the inlet axis and in the center of the FLEC. Different air velocities may influence the VOC-emission of a certain sample (6): the transport of emitted VOC to the chamber outlet may be reduced and the emission itself may be decreased due to a thicker diffusion layer. This effect could possibly affect the measured VOC concentration at the outlet.

For evaluation of this effect a test plate was designed to characterize the influence of the inhomogenous flow field on punctual artificial emission sources.Turning the FLEC on the test plate makes it possible to determine the overall concentration deviation for designated emission points.

METHODS

The acrylic glass test plate was equipped with four emission sources by use of the following procedure: four holes were drilled into the plate and filled separately with with the molten 1,3,5-trichlorobenzene (S1), 1-bromo-4-chlorobenzene (S2), 1,4-dichlorobenzene (S3) and 1,2,3-trichlorobenzene (S4).After solidification the filled holes were polished to gain an even surface. The substances were easy to handle for this kind of experiment because they combine a sufficient evaporation rate with a melting point only 10 - 40 degrees above room temperature. One of the sources (S1) was placed in the center of the FLEC-covered surface, the second (S2) and third (S3) source were arranged in a straight line towards the cell's rim, having a distance of $r = 4$ cm and $r = 7$ cm to the FLEC center. The fourth source (S4) was positioned 90 deg to the S1-S3-axis with $r = 7$ cm (see inset of Figure 1). The distance between the FLEC-center and the inlet slit is 7.5 cm.
This constellation made it possible to always have one source in an area of high velocity and another one in an area of low air velocity, thus being able to exclude other influences than the cell rotation.

The rotation of the FLEC on the test plate was done counterclockwise in steps of 10 and 90 degrees. After an equilibration time of 15 min two air samples were collected on steel-tubes (Perkin Elmer) filled with 220 mg Tenax TA (Chrompack). The sample volume of 250 ml was taken with a sampling rate of 50 ml/min. The sampling tubes were analyzed with thermal desorption/GC-MSD (Perkin-Elmer ATD 400/Hewlett-Packard 6890).

RESULTS

The determined VOC concentrations were found to be between 3 and 15 µg/l for a total flow of 300 ml/min. Due to the different boiling points of the used substances no direct comparison of the concentrations was possible. To visualize the angle-dependency of the VOC concentration with punctual sources, the measured concentration after a complete turn (360 deg) of the FLEC is normalized to 100 percent and the deviation in percent is plotted against the rotation angle in Figure 1.

As expected, the influence of the rotation was neglectible for S1 (95-105%), for S2 a noticable effect (85 - 112%) could be determined. In contrast to the results of these inner positions, the sources directly at the inlet slit showed significant deviations from the measured concentrations. Source S3 is located in an area of high air velocity at the start of the experiment and therefore shows a high concentration that drops two times to about 70% of the initial value on a full turn of the FLEC. As expected, source S4, including a right angle with S3, shows the inverse behaviour of S3. While the mean emision rates of S3 and S4 were thoroughly different, the measured concentration deviations were quite similar.

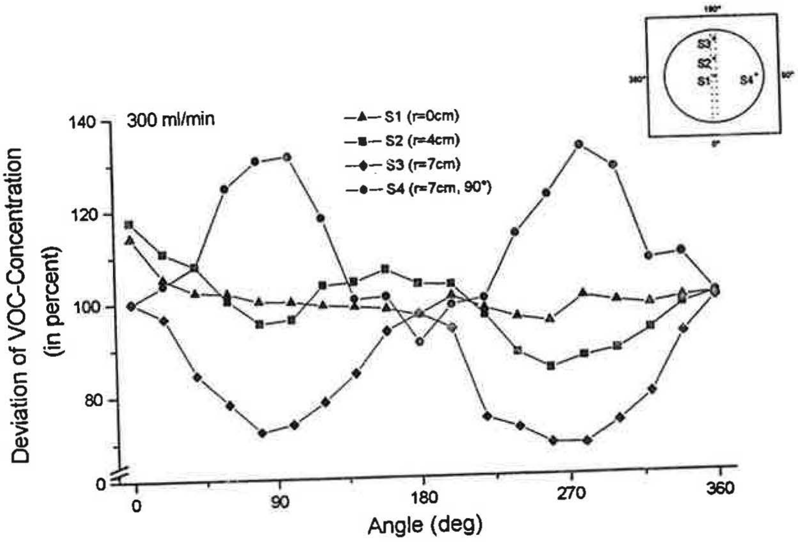

Figure 1: Dependency of the VOC-concentration deviation (in percent of the concentration after a full turn of 360 deg) on the rotation angle. Inset shows the location of the sources on the test plate.

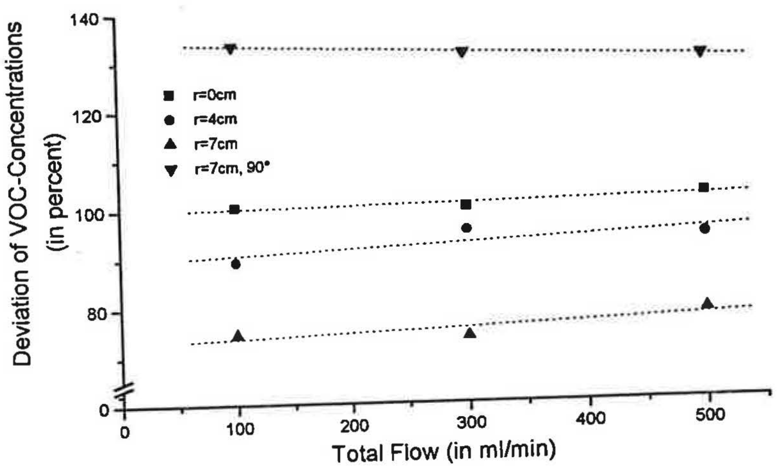

Figure 2: Dependency of the concentration deviation after a 90-degree-turn and the total air flow through the FLEC.

This experiment was repeated with two further air flow rates, 100 ml/min and 500 ml/min. Figure 2 shows the concentration deviations at an angle of 90 deg (minimal concentration for S2 and S3, maximum concentration for S4) against the total air flow.
The angle-dependent concentration deviation seems to be almost independent of the total flow, although the expected increase of the emission rates with rising flow rates was observed. The small decrease of the effect at higher air flow rates may be due to an increasing mixing in the cell. A non-radial component of the flow in the cell at higher air-exchange rates is probably reducing the angle dependency.

DISCUSSION

The presented results may have influence on general emission testing with the FLEC:

- different air velocities at the sample surface may lead to a different rating of a certain surface area. The higher flow over the surface area at the inlet axis should increase the transportation of volatile substances to the outlet from this area. It will therefore underestimate the surface area perpendicular to the inlet axis.
  The sample surface at the inlet axis will probably contribute a bigger part to the total VOC-content measured at the outlet.
  Regarding homogenous samples, this effect will certainly average out. As soon as the FLEC is used to test surfaces of unknown homogeneity, comparability of the results with those from other test chambers (including the FLEC itself) is not necessarily given.

- different air velocities at the sample surface will probably influence the emission of substances by changing the thickness of the diffusion layer. For diffusion controlled emission processes a further underestimation of the surface area perpendicular to the inlet axis may take place.

It is important to mention that this effect will only be measurable if the sample surface is not homogenous, i.e. contains knot-holes, encapsulated solvent residues or general surface inhomogenities like varying coating thickness.
As long as sufficient homogenous samples are tested the effect will average out and a satisfactory correspondence is given if test samples are analyzed with the FLEC at different directions.
If the homogeneity of a sample is doubtful, it would be a reasonable analytical procedure to analyze the sample twice with a 90 degree turn of the FLEC between the sampling processes.

REFERENCES

1 Wolkoff, P.; Clausen, P.A.; Nielsen, P.A. and Gunnarson, L. 1991. Field and Laboratory Emission Cell: FLEC. American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc.: IAQ'91, Healthy Buildings, Washington D.C., pp. 160-165

2 Wolkoff, P.; Clausen, P.A.; Nielsen, P.A. and Gunnarson, L. 1993. Documentation of the Field an Laboratory Emission Cell "FLEC": Identification of emission processes from carpet, linoleum, paint and sealant by modeling. Indoor Air, 3, pp. 291-297

3 Wolkoff, P. 1996. An emission cell for measurement of volatile organic compounds emitted from building materials for indoor use - the Field and Laboratory Emission Cell FLEC. Gefahrstoffe - Reinhaltung der Luft, 56, pp. 151-157.

4 CEC - Comission of the European Communities. 1991. Guideline for the characterization of volatile organic compounds emitted from indoor materials and products using small emission test chambers. COST Project 613, Report No. 8, Brussels.

5 Uhde, E.; Borgschulte, A. and Salthammer, T., 1997. Characterization of the Field and Laboratory Emission Cell - FLEC: Flow Field and Air Velocities, in publication.

6 Zhang, Y. and Haghighat, F. 1996. A small air velocity controlled test chamber for emission studies. In Tichenor B.A. (Ed.): Characterizing sources of indoor pollution and related sink effects. ASTM, STP 1287, West Conshohocken, pp. 23 - 33