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Review of Small Scale Devices for Measuring Chemical Emission from Materials

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Abstract

A review of published material covering small scale devices for measuring emission of volatile organic compounds (VOC) especially from building materials has been performed. The review is based on the international literature as well as patents, standard methods and devices for industrial application. Several small scale devices for emission measurements exist. A few of these devices are constructed for being attached directly to the surface of building materials on site. Stainless steel is the most frequently used material since the surface is smooth and inert. For low emission rate materials headspace technique provides too small amounts of volatile compounds. Existing microchambers for industrial use are mainly limited to very specific applications and the testing often performed at elevated temperatures.

Key words: test equipments, emission determination, critical review, building materials, volatile organic compounds.

SP
RAPPORT 1990:45
ISBN 91-7848-254-2
ISSN 0284-5172
Borås 1990

SWEDISH NATIONAL TESTING AND
RESEARCH INSTITUTE
REPORT 1990:45

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Preface

This review is focussed on devices for quantifying volatile compounds emitted from various materials. Building materials may affect the indoor air quality due to the large surface areas permanently exposed to the indoor air. Devices for emission determination are applied in various fields where low emitting products are required e.g. building materials, automobile interior trim and even material in space cabins.

The review therefore covers a large area of patents, standard methods and devices for emission measurements with industrial application. Most devices are limited to specific applications e.g. urea-formaldehyde bonded products. There is however a need for test equipments especially designed for emission measurements of various types of building materials. The review forms the basis for such a device in small scale, Field and Laboratory Emission Cell, FLEC. In contrast to traditional climate chambers, FLEC is intended for industrial production control and product development. The upper part of FLEC can be put on surfaces in order to characterize emission sources in laboratory or on site in buildings. Combined with the subunit the upper part of FLEC furthermore can be put on semi solid materials as sealants etc. FLEC is adopted as industrial standard by Swedish Flooring Trade's National Association. FLEC is presented in detail at the conference "Healthy Buildings '91".

We thank Peter A. Nielsen at the Danish Building Research Institute, Peder Wolkoff at the Danish Institute of Occupational Health and Björn Lundgren at the Swedish National Testing and Research Institute for fruitful discussions. This review is a part of the project "Design of a Field and Laboratory Emission Cell for various building materials" performed in cooperation with our Danish colleagues. This project has been supported by the Danish National Building and Housing Agency and the Swedish National Building Research Council.

Borås May 1991

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1. INTRODUCTION

Since indoor air quality may be affected by the emission of volatile compounds from building materials, it is crucial, that relevant technique for emission measurements of material is available. Climate chambers are widely used for emission measurements on various materials and even the basis for official regulations concerning formaldehyde from e.g. UF-bonded products. Traditional climate chambers in the range of m^3 are well suited for their purpose. However, this size of chambers are less suitable for industrial purposes or evaluation of materials on site in buildings.

This review covers only small scale equipments for emission measurements of materials and focuses on portable devices. Neither the term small scale nor portable can be strictly defined but several parameters ought to be taken into consideration such as weight, size, fragility, usefulness in the field etc.

In various applications measurements of emission of volatile organic compounds (VOC) have been demonstrated e.g. for building materials, packaging materials, solid waste, pesticides, fragrant compounds in the perfume industry, petroleum products, paints and other surface materials, as well as "fogging" in the automobile industry. The review consists of contributions from patents, standard methods and applications for research and development. The review does not include analytical procedures.

2. REVIEW OF DEVICES FOR EMISSION MEASUREMENTS

2.1 Ventilated versus Non-Ventilated Testing

Ventilated and non-ventilated testing can be identified as two main principles in emission testing of materials.

Non-ventilated testing is performed in a closed vessel without air exchange. The composition of the volatile organic compounds in the air over the surface of the specimen is determined by the vapour pressure for each compound. In order to analyse the gas over the specimen a headspace sample may be injected into a gas chromatograph. Vials, jars or desiccators have been used in emission measurements of various materials e.g. in (1a,2,3,15,20,31,45,53). Measurements have even been performed in rilsan bags (63). Vacuum techniques have also been applied (6,24,40,52). Headspace measurements is suitable for rapid screening of the emission profile of materials with a relative high emission. For low emission rate materials the headspace over these materials contain too little material to be tested by direct injection(39).

Ventilated testing is performed in a vessel with air exchange. A dynamic steady state concentration of a volatile compound is reached depending on the vapour pressure, the emission rate for the specific compound and the ventilation rate. Solid sorbents are often used to trap VOC's in the outlet air. Testing devices are usually ventilated with air, sometimes purified with activated carbon (16,32) or catalytic oxidation (51). Also ventilation with helium is reported (39,46).

Significant differences of the composition of emissions from products determined in chamber and in headspace air respectively have been observed and discussed in terms of polarity of the emitted compounds (10).

2.2 Chamber Volume

In non-ventilated testing the minimum internal volume of the vial, glass bottle etc is determined by the gas volume required for analytical determination, usually a few milliliters. Devices for ventilated testing usually requires larger volumes, 50 ml for the smallest ventilated micro chamber (60) and 180 liters for the largest portable chamber found (35). A comparison of results between two ventilated chambers differing in volume as much as six orders of magnitude, mL and m^3, respectively, show that the size of the chamber does not significantly affect the steady state level (27).

The loading factor is the ratio of the exposed surface area of the test specimen to the chamber volume. At given climate conditions the steady state concentration for a specific chemical compound is dependent on the loading factor and the air change rate. A theoretical model concerning factors which may influence steady state level of formaldehyde in chambers was introduced by Hoetjer (26). This model can be applied on chemical compounds even other than formaldehyde (61). An empirical mathematical model where decay time is taken into account is reported (11).

2.3 Chamber Materials Exposed to the Air

Stainless steel is the most frequently used material for climate chambers but even glass e.g. (7,34,48), brass (38), aluminium (44) or plexiglass (35) are reported to be in use. In order to avoid adsorbtion or high background level, it is essential that the surfaces exposed directly to the chamber air are smooth and inert. It is also essential that the device is easy to clean. The importance of an appropriate cleaning procedure can not be overemphasized (32). Available information about materials used in devices, internal volumes and testing principles (ventilated/non-ventilated) are summarized in the table.

Information about test chambers available from the quoted literature references:

	Numbers		Numbers
Test principles		Cell materials	
ventilated	20	stainless steel	4
non-ventilated	15	brass	1
		aluminium	1
		glass	13
		polymers	4
Cell volumes (Litres)			
< 1	11		
1-9.99	9		
10-100	5		
> 100	5		

2.4 Regulation of Temperature

Emission measurements are often reported to be performed at ambient temperatures. However, for accurate determinations of the emission rate it is necessary to maintain the temperature within narrow limits. For e.g. industrial purposes certain testing climates at standardized atmosphere are recommended (30).

In order to enhance the emission, measurements are also performed at elevated temperatures. Among testing materials are caulks, sealants and particle boards (12,28,32,57). The highest found temperature for an industrial application is 90 °C in determination of fogging (14,44).

2.5 Air Mixing in Chambers

It is essential that there is sufficient mixing of the air in the chamber to avoid a thin stagnant air layer over the surface of the specimen (22,37). To avoid concentration gradients, many chambers are equipped with fans. Fans have also been combined with perforated plates (23). It is however difficult to use conventional fans without contributing to the air contamination, especially when measuring at the ppb-level. For specific purposes stirring within the chamber may be achieved by using completely sealed internal fans magnetically coupled to an external variable speed drive unit (36). In one device the air is well mixed by the high air velocity in the slot over the test specimen (27).

In well mixed chambers it has been shown that the steady state levels are not affected by nominal air velocities but only by the air change rate itself (27,35,29).In practice it is furthermore difficult to give a direct measure of the air velocity of the boundary layer over an emitting surface. This velocity depends on the air change rate and the mixing of the air. Theoretical models, for ideal mixed chambers can be used to check whether the air is properly mixed (1,26).

2.6 Emission Determination of Building Materials

Most devices for emission measurements are intended for building materials. Some are especially designed for the determination of formaldehyde from e.g. UFFI (50), paints (13,59) and for production control of UF-bonded woodbased panels (8,17,18,19,28,47,49,57). Pesticide emission from impregnated wood have been determined (9,29,42,62). Radon exhalation have been determined from various construction materials (33,43). Other building products as insulation materials, caulks, sealants, wood finishing materials, floor coverings and screeds have also been studied (4,16,32,54,56,58).

Some devices are especially intended for identification of emission sources in buildings in use and may be attached directly to the surface of a specimen on site. Even measurements on single walls has been performed. One advantage of such a measurement is its non-destructive nature with respect to the test object (3,21,25,38,41). For various building materials, olfactometric procedures in small open chambers have been demonstrated e.g.(5,55).

3. CONCLUSIONS

Several small scale devices for emission measurements exist.
Some of these devices may be assessed as being portable. A few of these devices are constructed for being attached directly to the surface of building materials on site. Especially for field applications, a device in metal seems to be more convenient than in glass. Stainless steel is the most frequently used material since the surface is smooth and inert. For low emission rate materials headspace technique provides too small amounts of volatile compounds. A sufficient mixing of the air over the test specimen in a small ventilated device can be achieved without fans. Existing microchambers for industrial use are mainly limited to very specific applications and the testing often performed at elevated temperatures.

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