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The Air Quality Laboratory at the Danish Building Research Institute

A Laboratory for Investigation
of the Air Quality
in Simulated Indoor Environments

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A LABORATORY FOR INVESTIGATION OF THE AIR QUALITY IN SIMULATED INDOOR ENVIRONMENTS

Synopsis

A laboratory, designed to form the basis for research aiming at increasing the knowledge concerning the interactions between indoor pollution sources and the indoor environment, has been taken into operation. One long term purpose of the activities in the laboratory is to develop theoretical models, based on experimental data, for the prediction of the air quality in real buildings. At present, the experiments focus on the relation-ship between the emission of pollutants from building materials and the environmental parameters, i.e. air temperature, air humidity, air velocity and pollutant concentration in the air. The measurements include sensory assessments by panels of air quality judges, as well as chemical analyses of a variety of gaseous and vaporized organic compounds.

The air-conditioning and ventilation system enables the environment in the laboratory to be controlled with high accuracy, as regards the thermal climate. The temperature and the air humidity in the laboratory can be varied within wide ranges. Low concentrations of polluting gases, vapours and particles in the supply air are ensured by the use of a charcoal filter in combination with a high-grade fine filter. The conditioned and filtered _ supply air enters the laboratory by a displacement ventilation system, which can be operated either with constant or variable airflow rates.

The present paper gives a description of the air quality laboratory and outlines the approach for the indoor air quality research at the Danish Building Research Institute (SBI).

1. Introduction

The quality of the indoor environment is determined by several factors which influence the comfort and well-being of humans. One such factor is the presence of polluting substances in the indoor air, i.e. the indoor air quality. The major sources of indoor air pollution can be found among building materials, ventilation system components (e.g. deteriorated filters), office equipment, people and the outdoor air. The prerequisites for a good indoor air quality are set in the process of the design and construction of a building and in the maintenance of the building in operation.

It is a common viewpoint that the preferred measure to minimize the risk of poor indoor air quality is to reduce the strength of the indoor pollution sources rather than increasing the ventilation rates. To realize this, research is needed to increase the knowledge about the factors which influence the interaction between the pollution sources and the indoor air. One main goal is to provide professionals involved in the building design process with tools to aid an appropriate building' design. This can, for example, be achieved by providing projectors the-opportunity to select materials with low emissions of pollutants under all of the physical conditions conceivable in the indoor environment being projected. Emissions from building materials are of special concern since this type of pollution has been found to cause a lasting sensation of odours, .as opposed to, for example, the sensory effects, caused by human bio-effluents, which usually disappear a few minutes after the start of the exposure, due to adaptation [1]. The emission of organic compounds from various materials used indoors can be studied using environmental chambers of different sizes [2,3]. Full-scale chambers can be used for testing large structures, combinations of materials and furniture, while small-scale chambers can be used for testing small samples of larger materials.

2. Lay-out and construction of the laboratory at SBI

The laboratory facilities consist of two adjacent ventilated full-scale rooms, of which the main room has a total volume of 96 m^3 and the ante-room has 'a volume of 32 m^3. The walls and the ceilings of the rooms consist of panes of glass mounted in aluminum frames and the floor consists of high-pressure laminated fibreboard. The main purposes for selecting these materials were to ensure a negligible sink effect and a negligible emission of pollutants from the inner surfaces of the laboratory. The two full-scale rooms are located in a 1800 m^3 hall, which is ventilated with an outdoor air change rate of about 4 h^{-1}. Figure 1 shows a photograph of the exterior of the air quality laboratory.

Figure 1. The exterior of the air quality laboratory with the main room to the left and the ante-room to the right. The ventilation and air- conditioning system and the duct-work are located at the roof of the laboratory.

Small-scale test chambers

The laboratory is prepared for the simultaneous use of up to 24 small-scale test chambers in order to facilitate the investigation of a large number of building materials, studied under different environmental conditions. These small-scale chambers, of the type CLIMPAQ (Chamber for Laboratory Investigations of Materials, Pollution and Air Quality), are made of glass and have each an internal volume of 50,9 litres. The CLIMPAQs can be removed from the laboratory in order to enable full-scale experiments with large structures or combinations of materials. Details about the construction and operation of the CLIMPAQ can be found elsewhere [4]. Figure 2 shows a photograph of one group of CLIMPAQs in the main room. Up to twelve CLIMPAQs can be installed in each of two groups.

Figure 2. The interior of the main room with one of the two CLIMPAQ-groups.

Air-conditioning and ventilation system

The air-conditioning and ventilation system enables the temperature and the air humidity in the laboratory to be varied within wide ranges. The temperature in the main room and the ante-room can be varied between 10°C and 30°C, while the possible temperature range in the CLIMPAQs is 10-40°C. The relative humidity can be varied in the range 30-70 %RH. The stability of the airflows to the CLIMPAQs is within ± 2%, while the temperature in the rooms and in the CLIMPAQs are controlled with an accuracy greater than ± 0.5°C.. The stability of the humidity control is ± 5 %RH at a relative humidity of 50%RH.

Low concentrations of polluting gases, vapours and particles in the supply air are ensured by the use of a particle filter of class EU5, a charcoal filter and a fine filter of class EU7. The conditioned and cleaned supply air enters the laboratory by a displacement ventilation system, which can be operated either with constant or variable airflow rates. The laboratory is operated at an overpressure of about. 10-15 Pa relative to the hall in which it is located. Some technical data for the air quality laboratory and the CLIMPAQ are presented in table 1.

Table 1. Some technical data for the air quality laboratory and the CLIMPAQ. The air change rates and the airflow rates are specified as the maximum capacities obtainable in both rooms simultaneously.

		Main room	Ante-room	CLIMPAQ
Volume	[m^3]	95.3	31.8	0.0509
Floor area	[m^2]	34.0	11.4	0.200
Maximum air change rate	[h^{-1}]	9.5	11.5	127
Maximum airflow rate	[l/s]	250	100	1.80

3. Methods for measurements of air quality and experimental parameters

There are several types of sources, conceivable for investigation in the laboratory, each emitting a variety of chemical compounds. At present the focus is on volatile organic compounds (VOCs) emitted from building materials and on how pollutants from materials are perceived by humans. Therefore the air quality measurements include both chemical analyses of the emitted compounds and sensory assessments of the air quality.

Chemical analysis

Identification and quantification of volatile organic compounds are carried out by sampling on adsorbents, subsequently desorbed and analyzed with gas chromatography, flame ionization detection and mass spectrometry. The adsorbent material is normally Tenax TA filled in stainless steel tubes for active sampling of VOCs. After the adsorbents have been exposed they are transported to a chemical laboratory for analysis. This method gives detailed information about the individual substances present. However, of practical and economical reasons the method can only give results with relatively low time-resolution.

The total concentration of VOCs (TVOC) is measured with high time-resolution using an instrument based on photo-acoustic spectroscopy. This method cannot give any information about individual VOCs, but gives the opportunity for screening the TVOC concentration in all of the 24 small-scale chambers as well as in the full-scale rooms and in the supply air.. The measurement system, which is controlled by a personal computer, includes automatic logging of the measured concentrations and automatic switching between all of these sampling locations. The minimum time-interval between two samples including purging of the sampling tube is about 1 minute. In addition to the TVOC concentration, the instrument can measure, for example, the total concentration of aldehydes.

Sensory assessments

The human perception of air pollutants from materials may be measured using sensory panels of judges assessing the air quality [5,6]. The sensory assessment may be based on the use of trained panels of about 10 persons. Each panel member is trained to assess the perceived air quality in the decipol unit. The decipol-scale is related to known con- . centrations of the reference gas 2-propanone. The perceived air quality can also be measured using an untrained panel of at least 40 judges. The air quality in the CLIMPAQ is assessed using a diffuser mounted at the air outlet of the CLIMPAQ. To ensure a low background concentration in the laboratory where the CLIMPAQs are located, this space is ventilated with the maximum airflow rate shown in table 1, when the panel members are carrying out their air quality assessments.

Experimental parameters

The supply airflow rates and the air temperature in each CLIMPAQ are monitored automatically and stored by a personal computer. The airflow rates are measured with temperature compensated hot-wire anemometers mounted in the supply air ducts to the CLIMPAQs. The inaccuracy of the measured airflow rate is typically less than 1:5% of the measured value. The temperatures in the CLIMPAQs, in the supply air and in the main room are measured with thermocouples with an inaccuracy of about ± 0.2°C. The air humidities in the CLIMPAQs are measured with the photo-acoustic gas analyzer described above.

4. Selection of airflow rates for the CLIMPAQ tests

The test parameters used during experiments are selected to represent realistic indoor conditions. In order to get a realistic concentration of pollutants the airflow rate is chosen based on a model room, so that the ratio between the ventilation rate and the material area, i.e. the area specific airflow rate in the CLIMPAQ is equal to the ratio in the model room. Table 2 shows an example of the calculated area specific airflow rates for different material types, using the Nordtest Model Room [7] ventilated with an air change rate of 2.0 h".

Table 2. Surface areas and area specific airflow rates for different material types in the Nordtest Model Room [7] ventilated with 2.0 h-1.

Material type	Surface area in the model room [m^2]	Area specific airflow rate at 0.5 h^{-1} in the model room [m^3/h per m^2]
Floor/Ceiling	7	4.83
Wall	24	1.41
Sealant	0.2	169

5. Studies recently carried out in the laboratory

This section summarizes the test-design and aim of two projects that recently have been carried out in the air quality laboratory. The purpose of presenting the test design is to give an indication of the approach and the extent of the experiments.

The influence on emission rate of the air velocity and the concentration

Five different new materials were tested under different conditions regarding the air velocity over the material surface and the concentration of the emitted pollutants. The materials were selected to represent frequently used indoor materials of different types, as regards the material thickness and surface structure. The test specimens were samples of an acrylic wall paint on gypsum board, waterborne varnish on beech-wood parquet, PVC floor, carpet of tufted nylon and an acrylic sealant. The tests were performed using three different airflow rates with a factor 10 between the minimum and the maximum values. The air velocities over the test specimens ranged from 0.05 to 0.20 m/s. Throughout the tests the air temperature and the relative humidity in the CLIMPAQs were held constant at 23°C and 50%, respectively.

The tests were carried out during three subsequent two-month periods involving the simultaneous use of 12 CLIMPAQ-chambers. Sampling for detailed chemical analyses and sensory assessments were carried out at days 1, 7, 14, 28 and 60.

Selection of flooring, materials for a planned building

Five floor coverings, competing for installation in a new airport terminal, were tested with respect to their inclination to emit pollutants to the air. The materials were newly produced and they were tested during a one month period under constant environmental conditions. The experiments included a study of the effect of cleaning agents on the indoor air quality.

6. Future research areas and projects

This section gives a brief presentation of various research projects that will be carried out in the air quality laboratory.

Indoor climate labelling of building materials

The danish standard for determination of emissions from building materials was adopted in 1994. The standard forms the basis for the activities within the Danish Indoor Climate Labelling of Materials [8], which is operated in collaboration with building material producers. The aim is to provide manufacturers with standardized methodologies for the development of "healthy" materials for indoor use. At present, the focus is on emission of organic compounds from newly produced building materials, and the method is based on both chemical analyses and sensory assessments in combination with mathematical modelling. The main feature of the approach is the calculation of an "indoor climate relevant" time value, which is an expression of the time required for the emission to decline sufficiently to result in an acceptable concentration of pollution in a standard room. The acceptable concentration thresholds are established from evaluations of the thresholds for both irritation and odour. The indoor air quality laboratory at SBI is a fundamental tool for further development and refinement of the labelling system.

Sorption processes, pollution sources and sinks

It has been shown that sorption of pollutants on indoor surfaces may be of importance to the indoor air quality. Adsorption on surfaces may reduce the maximum indoor concentration, but when the compOund, at a later stage, is desorbed the result will be an extended time-period required for the decay of the concentration of the pollutant in question (i.e. a prolonged exposure to pollutants). Future research will aim at an - increased knowledge about the influencing parameters and the sorption characteristics of various indoor materials. The basic knowledge will be obtained by the use of micro-balance studies, based on gravimetric weighing of small material samples. The transfer to real conditions will be obtained by studies based on concentration measurements in the CLIMPAQ chambers and full-scale experiments.

Mould growth on building materials

Growing knowledge on the impact of mouldy materials in water damaged buildings in relation to human health has resulted in model studies in CLIMPAQs. Type of mould as well as their metabolic products, which may have health implications, have been identified. Observations, such as irritation from eyes, skin and mucosa have been experienced by the test panels assessing the air quality in the chambers with mouldy materials.

Further development of methods for sensory characterization of emissions

It has been shown that the exposure-response relationship between the concentration of air pollutants from materials and the perceived air quality differs between materials and that the relation may differ from the corresponding relation for human bio-effluents [6]. Furthermore, the sensory emission rates determined by sensory assessments are not constant, but may depend on the concentration level they are determined at. In order to be able to model the perceived air quality, in spaces where concentrations may vary, the exposure-response relationship needs to be known. This is achieved by assessing the air quality at least at two different concentration levels for each material type. For this purpose a dilution system, for use in combination with the CLIMPAQ, is under development. The system enables mixing of the polluted exhaust air from the CLIMPAQ with unpolluted supply air. In this way it is possible to produce different concentration levels of the pollutants emitted from a certain material.

Full-scale experiments

The smaller of the two rooms in the laboratory, the ante-room, is used as a reference chamber for the passive tracer gas technique (PFT-technique) developed and used by SBI [9]. Moreover, in the future, there will be an increased need for a full-scale laboratory facility, e.g. when the models developed by the use of results from small-scale emission testing are to be verified by comparison to full-scale experiments. To meet these future demands, the CLIMPAQs can be removed from the laboratory, which creates a full-scale laboratory facility, consisting of two test chambers of 32 m^3 and 95 m^3, respectively. With this flexible solution it is also possible to carry out experiments in the field of air distribution in rooms.

7. Conclusions

In the air quality laboratory at the Danish Building Research Institute the main parameters of importance to the indoor air quality can be controlled and monitored with high accuracy. Independent experiments can simultaneously be carried out in up to 24 small-scale test chambers. The high test capacity makes it possible to perform detailed and extensive studies of the interaction between the indoor air and the indoor building materials. Due to the flexible design, the laboratory can easily be prepared for a wide variety of investigations within the fields of indoor air quality and ventilation.

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References

[1] Gunnarsen, L. "Adaptation and ventilation requirements", Proceedings of the Indoor Air '90 Conference, V1, pp 599-604, Toronto, 1990.

[2] Commission of the European Communities, "Guideline for the characterization of volatile organic compounds emitted from indoor materials and products using small test chambers", Report EUR 13593 EN, 1991.

[3] Commission of the European Communities, "Determination of VOCs emitted from indoor materials and products, Interlaboratory comparison of small chamber measurements", Report EUR 15054 EN, 1993.

[4] Gunnarsen, L., Nielsen, P.A. and Wolkoff, P. "Design and characterization of the CLIMPAQ chamber for laboratory investigations of materials, pollution and air quality", Indoor Air, 4, pp 56-62, 1994.

[5] Bluyssen, P.M. "Air quality evaluated by a trained panel", Ph.D. Thesis, Laboratory of Heating and Air Conditioning, Technical University of Den-mark, Lyngby, 1990.

[6] Knudsen, H.N, Clausen, G. and Fanger, P.O. "Sensory characterization of emissions from materials", Submitted to Indoor Air, 1995.

[7] Nordtest Method, "Building materials: Emission of volatile organic compounds, chamber method", NT Build 358, Esbo, 1990.

[8] Wolkoff, P. and Nielsen, P.A. "Indoor climate labelling of building materials: Chemical emission testing, modelling and indoor relevant odour thresholds", National Institute of Occupational Health, Copenhagen, 1993.

[9] The Nordic Building Research Cooperation Group, NBS-I, "The development of the PFT-method in the Nordic Countries", Ed. Säteri, J., The Swedish Council for Building Research, Stockholm, 1991.