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# EVALUATION OF THE INDOOR AIR QUALITY AS A CRITERION FOR MINIMUM VENTILATION RATES

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## 1. Introduction

Although people spend 70% of their time either at home or in public buildings such as schools, offices, transportation vehicles and terminals, and restaurants, they are more critical towards ambient or outdoor than indoor air pollution. For the following reasons, however, a thorough investigation of indoor air pollutants is necessary:

- Because of the reduced natural and mechanical ventilation in order to save energy for space heating, a general deterioration in air quality is to be reckoned with. This leads us to the question of minimum air ventilation rate necessary to achieve the desired air quality and to avoid the possible impairment of health and performance.

- The second point is the use of modern building materials, furniture equipments and consumer products which can emit noxious substances in air. The resulting effects on health, specially the long-term effects, are not yet known. The chief interest lies here in adopting strong regulations for the permission of materials and products, increasing the checks and thereby reducing the health risk to a minimum.

This paper reviews the pollutants occurring in indoor air. It is based on the papers presented at the international symposium on indoor climate (8), report of the WHO working group on health aspects related to indoor air quality (11), technical meetings on energy conservation (6, 7), and specific investigations on occurrence and effects of indoor air pollutants.

## 2. Sources and nature of pollutants

Important air pollutants are listed in Table 1. Although we shall not deal here with the pollutants in outdoor air, it should be kept in mind that the pollutants in outdoor air can influence the pollutants in indoor air considerably. Indoor air pollution is caused largely by human activities and behaviour. The type and rate of ventilation should be planned accordingly.

Man himself impairs the indoor air quality by continuous emission of heat, humidity, carbon dioxide, particles and perspiration. Rise in temperature, relative humidity and concentrations of different pollutants depend on the space occupancy and activities of individuals therein. The most common parameters to evaluate the human impact on indoor air quality are carbon dioxide ($CO_2$) and odour.

Various kinds of pollutants are caused by human acitvities. In residential buildings they consist primarily of dust caused by normal working and odours from cooking and smoking. Vapours from cleaning agents and solvents, set free while doing normal household chores, are also worth mentioning.

Table 1: Air contaminants

Important sources of air contaminants in residential buildings are listed. Indoor air quality is determined by odours, components of smoke, carbon dioxide and emissions from materials.

| Source | Pollutant |
|---|---|
| **Outdoor air** | |
| Space heating | Sulphur dioxide |
| Motor vehicles | Oxides of nitrogen |
| Industry | Carbon monoxide |
| | Oxidants |
| | Hydrocarbons |
| | Particulate matter |
| | Lead |
| **Indoor air** | |
| Man | Odours |
| | Carbon dioxide |
| | Water vapour |
| | Particles |
| Tobacco smoke | Carbon monoxide |
| | Aldehydes |
| | Particles |
| Consumer products | Odours |
| Sprays | Solvents |
| Cleaning agents | Organic Compounds |
| Combustion of gas | Oxides of nitrogen |
| for heating | Carbon monoxide |
| and cooking | Particles |
| Materials | Aldehydes |
| Particle boards * | Asbestos |
| Building materials | Radon |
| Paints | Solvents |
| | Organic materials |

* = Chipboards

The use of gas or oil for heating and cooking purposes gives rise to oxides of nitrogen and carbon monoxide due to insufficient combustion. This can lead to acute and chronic damage to health depending upon the concentration and duration of exposure. In this connection combustion of dust should be mentioned. This is what happens in case of warm air heaters and electric storage heaters where heating and burning of dust particles take place. The studies have shown that even in normal operating conditions different reaction products like carbon monoxide, carbon dioxide, oxides of nitrogen, and ammonia are formed. But even in case of heavy dust load the resulting concentrations were not dangerous to health (10).

Smoking of cigarettes, cigars, and pipes constitutes an important source of pollution which directly affects the indoor air quality. Depending upon the intensity of smoking, as well as size and ventilation of room, the concentrations of contaminants can reach the levels which not only cause annoyance but can even damage the health of sensitive persons like patients with heart and cirulatory ailments, asthmatics, and children. Studies have shown that concentrations of carbon monoxide, aldehydes, and particulates should be carefully watched in the rooms where smoking is permitted. In case of insufficient ventilation, carbon monoxide levels can exceed the long term standard of 9 ppm (4).

Still less is known about the possible pollution due to building materials, furniture fixtures, floor coverings, paints and coatings. Pollution caused by these sources is independent of behaviour and activities of inhabitants. Take for example Particle boards or chipboards which are used in furniture as well as in interior decoration. Aldehyde containing products are used in manufacture of these particle boards which may have

residual aldehyde that could continuously contaminate the indoor air and cause irritation of eyes and respiratory organs (3).

The question is still open if other organic solvents besides formaldehyde are also emitted. In any case, close examination of building materials with respect to solvent residues is recommended in future.

Another undesirable component in building materials is radon. In case of reduced ventilation, radon containing bricks could cause increased radioactivity in indoor air (11).

Asbestos is a further example of material hazardous to health. Asbestos is used in various building and insulating materials which can pollute the indoor air beyond permissible levels (11).

## 3. Studies done at the Institute of Hygiene and Work Physiology:

At the Institute of Hygiene and Work Physiology of Swiss Federal Institute of Technology in Zurich, we have two ongoing projects dealing with problems of indoor air quality. In one of them we study the air pollution caused by men; in another we concentrate on pollution caused by materials. The aim of both projects is to prepare recommendations for minimum ventilation rates based on the effects of various parameters on air quality.

Besides measuring physical parameters like temperature, relative humidity, carbon dioxide content of exhaled air and formaldehyde from building materials, we are interested in the contribution of odours to the air quality.

Schematic disposition of both the projects on "minimum ventilation rates" is shown in Figure 1.

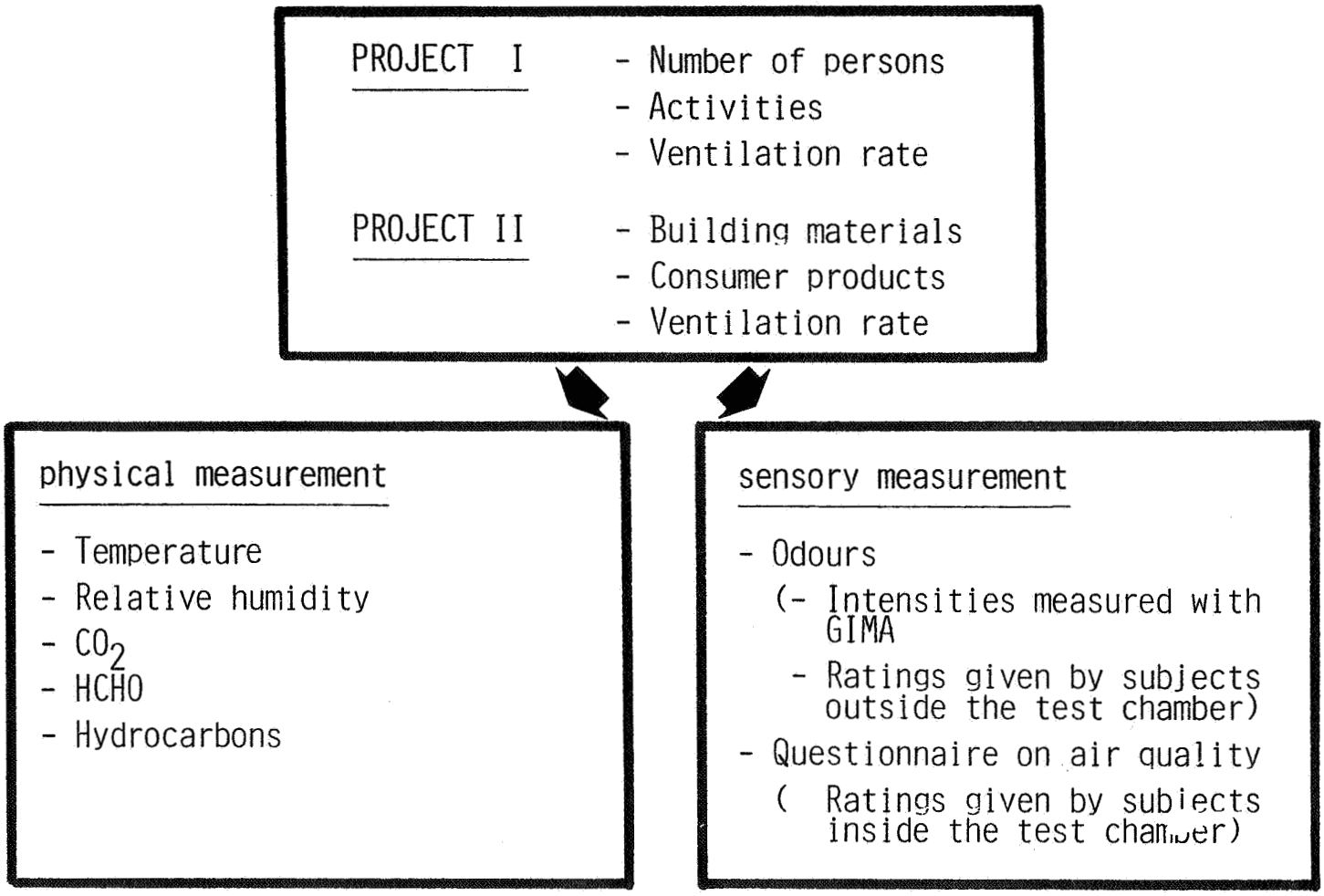


Figure 1:
Schematic presentation of both the projects on "minimum ventilation rates". The central block represents the room under investigation with its known parameters. Variables in Project I are human beings and their activities. Variables in Project II

are building materials and consumer products. Ventilation rate is an additional variable in both the projects. The evaluation of air quality is achieved by physical (temperature, relative humidity, $CO_2$, HCHO, Hydrocarbons) and sensory (odour intensity measuring instrument GIMA) measurements and by questioning the subjects in the test chamber.

Methods of odour investigation:

For several years our institute has been dealing with problems of odour annoyance. Initially we employed a pure physico chemical method of gas chromatography, but with limited success. So now we have switched over to sensory techniques taking help of the human nose as a detector. We are now in a position to evaluate the odour perception of subjects in a test panel formed by four or six persons of an average odour sensitivity. We have developed our own instruments for these odour investigations. For sensory evaluation of odours, there are two alternatives:

For determining an odour threshold, the odourous air is diluted with odour-free fresh air till the odour can just be perceived. That concentration is termed as odour threshold. The ratio of odour-free to odourous air is expressed as dilution number.

For determining odour intensity, the stream of undiluted odourous air is presented to the subjects. The intensity of odour perceived can either be expressed on verbal scale (e.g. no odour/ very faint odour/ faint odour/ distinct odour/ strong odour/ very strong odour) or directly in comparison to standardized odours (e.g. pyridine, hydrogen sulfide).

Strong odours as emitted by waste incinerator units and by sewage treatment plants can very well be investigated by either of these two methods (5). Weak odours like those emitted

from human bodies can only be judged with the help of odour intensity, because the odour concentrations are so near the threshold values that further dilution is practically impossible.

For investigating the air quality in connnection with minimum ventilation rates, an odour testing apparatus called GIMA was developed: The air to be evaluated is sucked out by a fan from the test chamber and forwarded to the sniffing points via a valve-controlled piping system. All the parts which come in a direct contact with the sampled air are made of glass or Teflon. The sniffing points are so designed that two subjects can simultaneously participate in the experiment. The valves can be adjusted to achieve an air stream of 0.5 m/s at the sniffing points.

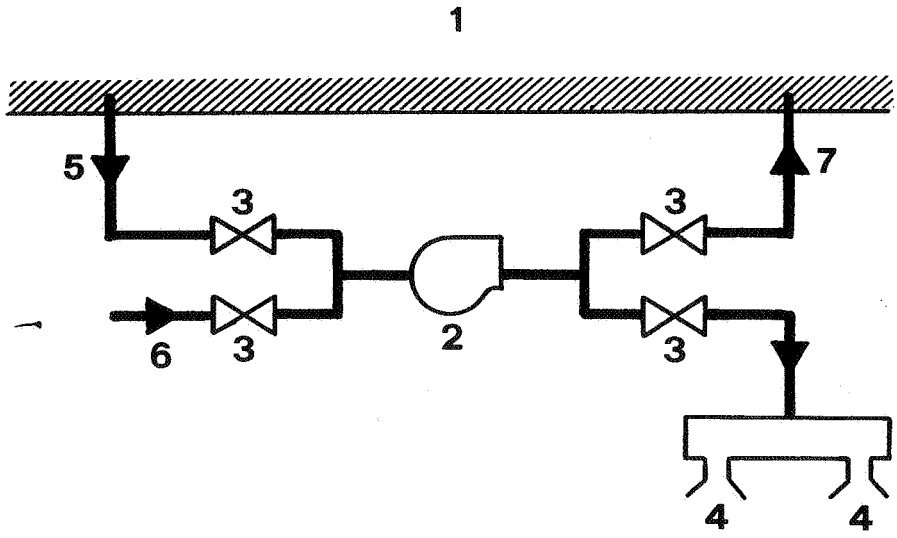


Figure 2: Odour testing apparatus

1. Test chamber
2. Fan
3. Steplessly variable valve
4. Sniffing points
5. Sample air
6. Standard air
7. Backflow of sample air

## 4. Conclusions:

All the contaminants which impair the indoor air quality should be eliminated at their source so far as possible. Control measures to reduce emissions are necessary especially in the case of outdoor air pollution. For indoor air, contaminants arising out of materials should be avoided. To this end strict permit regulations and increased checkings are necessary. Since the elimination of pollution due to smoking requires a long ventilation time, smoking - at least in public buildings - should be restricted to a few rooms only.

Pollution caused by human presence and activities could be taken care of by regulating the supply of fresh air, i.e. ventilation.

Present recommendations about fresh air requirements of rooms or enclosed places are based on practical experience. Scientific study of the problem of building ventilation was started as far back as the 18th century (9). But until today no leading compound could be found for evaluating the air quality. This can be done only for certain work places with high concentrations of specific contaminants.

It is therefore urgently necessary to objectify the problem of indoor air quality and to work out recommendations for minimum air requirements or to replenish the existing guidelines as is the case with USA and Sweden.

The important problem here is whether the necessary fresh air can be secured by natural ventilation - even when the windows are closed. For this, knowledge of the air ventilation rate of the room is necessary. Calculations show that in case of traditional construction style and average occupancy and use of

residential buildings, the demand of fresh air is only partly met by air exchanges through joints and cracks. If the air exchanges are not guaranteed through natural ventilation, additional window ventilation or mechanical ventilation systems should be provided according to the needs.

## 5. Summary:

Recently all industrial nations are making efforts to conserve energy by optimising building insulation. In this connection the hygienically relevant question arises as to how far the indoor air quality is modified by such measures. Investigations are under progress to evaluate the air quality as a function of occupancy, activities, and ventilation rate. The decisive criteria are temperature, relative humidity, carbon dioxide, odours and contaminants from consumer products and building materials.

Based on occupancy and proposed use of the room, guidelines for a minimum ventilation rate should be drawn.

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