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INDOOR AIR QUALITY AND ENERGY-OPTIMIZED VENTILATION

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Abstract: *The artificial environment is the source of engineering problems related to the indoor pollution. This paper discusses the reliable criteria to be established for indoor air quality and buildings' ventilation to achieve a healthier indoor environment. The objective is to ensure that indoor air produces no harm to health and no impairment of well-being.*
Key words: *indoor, pollutants, ventilation, energy.*

1. INTRODUCTION

The Constitution of World Health Organization (WHO, 1948) defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity". Modern people spend 90 % of the day indoors, a good indoor air quality being a human right. With the experience of sick building syndromes, the outdoor intake is considered a very important technical solution and the indoor air quality is an important criterion to evaluate the environment. Energy saving is another important item to take into account. The main purpose of most ventilation systems is to provide a health and comfortable indoor climate for the building's occupants. One of the main criticisms of an air conditioned space is the indoor air quality. Subjective response includes a lack of freshness, dryness and poor temperature control. Objective measurements indicate temperature outside the normal recommendations, high levels of pollutants, low relative humidities. The following parameters have a critical influence on the ventilation rates (the volume of outside air actually introduced into the space): the impairment of the air quality caused by occupants, emissions from materials in the room, activities such as smoking, the quality of outside air, the thermal load (Popa, 2003).

2. ARTIFICIAL ENVIRONMENTS

If an air-conditioning system is installed in a room, it automatically changes into an artificial environment and an appropriate control of all environmental elements should be carried out:

a. Ventilation efectiveness considers the mixing of supply air in an occupied space. It describes the fraction of fresh air delivered to the space that reaches the occupied zone. The proportion of fresh air that is delivered to the occupied zone of a space depends on the room air distribution which is determined by the location of the air delivery and the geometry of the space (ASHRAE, 1989). Ideally 100% of fresh air should be delivered to the breathing zone, but often the air short-circuits between the supply and extract points. Ventilation efficiency is the term used to quantify ventilation effectiveness, being a measure of the ability of a ventilation system to exhaust the pollutants generated within a space. For a specific pollutant it is the ratio of its concentration at the point of extract to the mean concentration level of the pollutant throughout the occupied zone. Ventilation efficiency (E):

$$E = C_e / C_l \quad (1)$$

Where C_l – concentration of pollutant at a location;
C_e – concentration of pollutant at exhaust

If there is a significant level of a pollutant in the supply air then this should be subtracted from the internal concentration levels (Ott, 2007.).

b. Exposure to indoor air pollutants

The dose of a man is expressed by the equation

$$D = q \int C(t)dt \quad (2)$$

Where D – the dose, q – rate of respiration
C(t) – concentration of the contaminant, t – time

The concentration in a room can be expressed as following if the instantaneous mixing is postulated:

$$C = Co + \frac{M}{Q} \quad (3)$$

Where C_o – outdoor concentration
M – contaminant generation rate
Q – ventilation rate

From equation (3) it derives the increase of indoor concentration over that of outdoor air as

$$\Delta C = C - Co = \frac{M}{Q} \quad (4)$$

Where ΔC – indoor concentration in excess over outdoor air concentration,

c. Related elements

The equation (4) shows that the increase on indoor concentration compared to the outdoor air is proportional to the generation rate and inversely proportional to the ventilation rate. This postulates a constant state and the average over a long period of time. These elements are the function of time and influenced by the changes of climate and human behaviour.

The generation rate M is also a function of human activities, quantity of contaminant existing and climatic conditions. The ventilation is also dependent on the life-style of residents, weather conditions and quality of building (Popa et al., 2008).

The quantity of existing pollutant is often decided by climatic conditions or by other conditions as in the case of fungi and mites growing on building materials or air-conditioning apparatus.

3. POLLUTANTS AS INDICATORS

The existing pollutants from an environment can be either independent, additive or synergetic.

In environments where industrial hygiene is applied, there are few significant pollutants originated from the production processes and they are monitored to protect the workers. If ventilation is applied, it usually dilutes other contaminants generated at the same time. In an ordinary environment, the pollutants are generated at low levels, without significant amounts of toxics. If the health effect is additive for each component, the relation between the concentration and the maximum permissible concentration of each pollutant is expressed as follows:

$$\frac{C_1}{C_{mp\,1}} + \frac{C_2}{C_{mp2}} + ... + \frac{C_n}{C_{mpn}} \le 1 \quad (5)$$

If a material ≠ i is selected as indicator, the equation (5) can be converted into the next equation:

$$\frac{C_i}{C_{mpi}} \le 1 - \left(\frac{C_1}{C_{mp1}} + \frac{C_2}{C_{mp2}} + ... \right) \quad (6)$$

The concentration allowed to the indicator is much lower than the concentration specified as maximum allowable concentration.

Equation (3) emphasizes that the indoor concentration of a pollutant is caused by two elements: the introduced outdoor pollutant and the indoor generation, the last having a greater impact on the indoor pollution.

If a puff of high concentration is transported from a source to a building, a certain part of the pollutant will enter the building depending on the time of stay at the site and the rate of infiltration or outdoor air intake. If the ventilation rate is reduced the amount introduced indoors is relatively small, leading to low concentrations especially if the pollutants are of high adsorption characteristics (Yanagisawa et al., 1996).

On the contrary, the indoor generated contaminants are present in the building even at low concentrations, until removed by ventilation.

The equation to predict the concentration of pollutants in indoor air postulate instantaneous uniform distribution. Although the prediction of spatial distribution is possible with numerical analysis, more research is needed.

The actual non-uniform distribution of pollutants indoors emphasized a variety of modes by rooms' characteristics. In ordinary air-conditioned rooms, the mixing of air is not significant after the supplied air was distributed throughout the room. If a puff of pollutant was generated from one point of a room, it will be transported by the general flow pattern to the exhaust opening as a diffusing puff. If the contaminant is continuously generated it will create a belt of 1 to 1.2 m in width where the concentration is consequently much higher than the average value (Godish, 2004).

4. ENERGY-OPTIMIZED VENTILATION

Apart from maintaining thermally comfortable indoor conditions, the principal aim of an indoor air system is to ensure good indoor air quality while consuming the minimum of energy. The principal measures for reducing energy consumption in ventilation and air conditioning systems are as follows:

- Establish constructional, operational and organizational conditions which will facilitate low energy consumption in the system.
- Carefully investigate the need for the proposed application
- Determine sizing criteria in accordance with actual demand.
- Use components with high efficiency levels across the whole operating range. - Design systems for demand-controlled operation and operate them accordingly. Demand controlled ventilation systems reduce costs even more substantially and without reducing the required degree of comfort.
- Ensure that the relevant operating parameters and energy consumption can be measured and undertake these measurements regularly during operation.

One of the most effective measures for the optimization of energy consumption for the distribution of air is to separate the thermal conditioning of the air (heating and cooling) from the air renewal process, by using radiator-type systems for heating or cooling. This means that the flow rate of the air discharged into a space can be limited to the outside air flow rate actually necessary for hygiene purposes. From the point of view of energy consumption, the outside air flow should be based on the required volumetric flow rate per person (Fitzner, 2000).

Energy-optimized solutions are possible if:

- Sources of pollution are avoided, or the emissions are at least extracted locally;
- The movement of the air (from the supply vent to the extract vent) is optimized (ventilation effectiveness) or if the air is discharged in the vicinity of people
- Smoking is prohibited. If this is not possible, the design flow rate for the outside air must be based on the estimated number of cigarettes per hour (50-130 m^3 per cigarette);
- The volume of air per personne is relatively large (time delay for the dynamic response of the air pollution load in a mixing system);
- Tobacco smoke pollution in small spaces (up to 100 m^3) can be reduced with air purifiers.

In air-only systems where the thermal load is such that supply air volume required is greater than the outside air rate dictated by hygiene requirements, the additional air should be supplied in form of recirculated air. Recirculated air should be used only where there is little or no pollution caused by work processes, unless the recirculated air is suitably filtered so that it is of the same quality as the outside air.

5. CONCLUSIONS

The target of environmental control is the health of people according to the definition of health by WHO. A necessary activity of professionals is to establish criteria that ensure that indoor air quality is adressed and hopefully prevented. All requirements must be feasible in practice. Outdoor air intake is a basic measure to cover the unknown pollutants. The energy-optimized ventilation must adapt the influencing variables both intrinsically and in relation to the overall system.

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