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THE CORRECT INDOOR AIR QUALITY ASSESSMENT: THE BASIS OF ENERGY CONSERVATION WITHIN BUILDINGS

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The microenvironment theory (Jokl 1989) differentiates the indoor climate into "constituents" formed by exposing agents. Each constituent level is assessed on the basis of its a) physiological and b) psychological strain of man. New mutual evaluation scales are proposed:"The Microenvironment Level" based on physiological strain and "The Microenvironment Quality", "The Microenvironment Sensation" reflecting the psychological strain on the subject´s feelings. Ranges - optimal and acceptable - are introduced for the regulatory ability an sensitivity of the human body. The presented theory is applied to the odor constituents as a contradiction with Fanger´s evaluation system.

INTRODUCTION

Trying to solve the problem of "Sick Building Syndrome" the suitable indoor climate assessment is discussed as a starting point for any attemp in this field. In 1988, for example, the new system for indoor air quality evaluation, based on "olf" and "decipol" was proposed by Fanger.

"CONSTITUENTS" INSTEAD OF "AIR QUALITY"

Usually hygrothermal, acoustic and lighting microclimate are assessed separately. The question is what to do with "air quality" because it is the result of many components impact. From the theory of the microenvironment (see Jokl 1974, 1989) it is evident that the agents forming exposing flows, so called "constituents" must be respected: odor, toxic, aerosol, microbial, ionizing, electrostatic, electromagnetic and electroionic ones.

PSYCHOLOGICAL AND PHYSIOLOGICAL STRAIN: THE NECESSARY BASES OF MICROENVIRONMENT EVALUATION

Each constituent level can be evaluated in two ways:
a) starting from subject´s feelings, i.e. from psychological strain of man, b) starting from physiological strain of human body.

The subjective approach is the most popular - even ASHRAE definition of environment comfort is based on it: "That condition of mind which expresses satisfaction with the environment". That means the environment can be assessed just by the statistical evaluation of respondents´responses. The same situation is with Fanger´s system for odor[x] constituent evaluation which also starts from subject´s feelings.

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[x] Fanger has stated for "indoor air quality" evaluation, but a) "olf" is from "olfaction" (Fanger´s statement), b) aerosol, microbial, ionizing and electroionic agents mostly do not smell even if they participate on indoor air quality.

The second approach is based on physiological strain (or post-strain, see Jokl 1989) of exposed subject, i.e. the real agent (thermal, odor etc.) impact on subject, produced by agent´s flow into the organism. For example an odor agent´s flow surrounds olfactory cells so exposing the olfactory organ.

Even if the result of both approaches correspond mutually the first could not be used instead of the second. For example odor constituent feelings could be false due to a) the masking effect of some odor agents, so called deodorants: the original agents remain but they are not perceived, b) some odor agents increase their effect mutually, but other do not, c) so called "inversion" caused by some odor concentration or by some odor combination: unpleasant odors are changing into pleasant ones and other way round, d) the temperatury decrease of olfactory organ sensitivity by some odor agent´s concentration.

Decisive criterion should be the human health (e.g. the olfactory organ s health) if we like to talk about "healthy" buildings. Thus the second method of evaluation must be preferred: starting from the agent´s flow into the subject and providing factors which determinate them where there is insufficient information for their estimation. The acoustic constituent is interesting from this point of view: original assessment system, based on the decibel perception of different frequencies is substituted by sound intensity measurement, i.e. by specific acoustic energy flow into the subject.

The preferred second or physiological approach is also supported: a) by the differential equation of the microenvironment, b) by the theory of stress (see Jokl 1989).

Note: Later on Selye (1974) has changed the terminology: stress has changed to stressor and strain to stress.

If we analyze human body strain, there are the physiology and the psychology in man which reflect the impact of the environment (see Table 1.). Two kinds of strain are produced: a) physiological (by the interaction of the environment and the physiological processes in human organism), b) psychological (by the interaction of the environment and psychological processes in human body).

The level of interaction (mostly equilibrium) between man and his environment is decisive for the physiological strain; the highest level - the harmony it reaches within the comfort zone. Only specific symptoms are produced, i.e. characteristic ones for the evaluated stress.

The feelings of subject, being the symptoms at the same time, are decisive for the psychological strain; they are specific (characteristic for the evaluated stress) and non-specific ones (common for various stresses: a) being bothered with the evaluated stress, b) being afraid of one s health).

For example a hot environment affecting the physiological processes produces sweat as a result of the body equilibrium with its environment. Thus physiological, just specific symptom is the excreted sweat. From psychologic point of view we feel hot (specific psychological symptom) as well as a) we are bothered with hot environs, b) we are afraid of our health (e.g. even a small draft may cause lumboischiadic syndrome)(non-specific psychological symptoms).

It is evident from the theory of stress that the human body strain is decisive for the environment impact on man and not only psychological one, produced by subject s feelings, but, first of all, physiological one as a result of the physiological response to the exposing environment.

THEORY APPLICATION IN PRACTICE

Starting to evaluate the microenvironment level, the physiological response must be estimated first (e.g. if we are in comfort zone, perspiration (sweating) zone etc.) on the basis of measurement of physiological values. As a result we obtain the microenvironment level. Then the psychological response should be investigated by means od special ballots checking the feelings of a subject. It is possible to achieve it by two ways: directly, asking what is the microenvironment quality (i.e. asking for both specific and non-specific symptoms at the same time, see Microenvironment Quality Ballot), or first asking what is the microenvironment sensation (i.e. asking for specific response only, see Microenvironment Sensation Ballot) and so to obtain the possibility of confrontation with the direct evaluation.

MICROENVIRONMENT SENSATION BALLOT	MICROENVIRONMENT QUALITY BALLOT
0 (2) Comfortable Range	0 (3) Optimal Range
1 (2) Slightly Uncomfortable Range	1 (3) Acceptable Range
2 (2) Uncomfortable Range	2 (3) Long Term Tolerable Range
3 (2) Very Uncomfortable Range	3 (3) Short Term Tolerable Range
4 (2) Dangerous Range	4 (3) Intolerable Range

The microenvironment quality may depend on time.

THEORY APPLICATION TO ODOR CONSTITUENT

Let us to apply the presented theory to the odor microclimate. There is the speciality of this microenvironment constituent: Odors can be pleasant or unpleasant. Pleasant odors are in the center of interest of perfume companies: thus just unpleasant ones are discussed.

An odor rate into the human body from the environment $\dot{m}_{odor}$ should be the criterion from physiological point of view:

$$\dot{m}_{odor} = \dot{V}\rho_{odor} \quad /mg.h^{-1}/ \qquad (1)$$

where $\dot{V}$ = inspired air volume $/m^3 . h^{-1}/$

ρ_{odor} = odor concentration within inspired air $/mg.m^{-3}/$

There is the relationship between human activity, expressed in metabolic heat production $(H/A_D) = \dot{q}_m$, and inspired air volume:

$$\dot{V} = (1/\rho_a)0.0052\ A_D\ \dot{q}_m = 0.0082\ \dot{q}_m \quad /m^3.h^{-1}/ \qquad (2)$$

where ρ_a = 1.2 the inspired air density $/kg.m^{-3}/$

A_D = 1.9 DuBois surface (European Standard Man) $/m^2/$

$\dot{q}_m$ = metabolic heat production $/W.m^{-2}/$

Thus

$$\dot{m}_{odor} = \dot{V}\rho_{odor} = 0.0082\ \dot{q}_m\ \rho_{odor} \quad /mg.h^{-1}/ \qquad (3)$$

That means that the odor impact on human organism depends on a) odor concentration within inspired air, b) subject s activity

For practical application limit values are desirable: optimal and acceptable.

There are so called "Threshold Odor Concentrations." (concentrations which can be identified by olfactory organ) which can be supposed as the upper limit of the optimal range of the odor microclimate for a sedentary subject (Brennan 1963, see Jokl 1989); odor limits based on them are listed in Table 2. I propose a new unit for each of them, called olf[x].

x In honor of Professor Paul Ole Fanger, Technical University of Denmark

E.g. 2 olf_{CO_2} means that the optimal odor limit of CO_2 was overpassed twice.

Based on the analysis of smell abilities of 1955 subjects (1158 women and 797 men at the ages of 5 to 99) it was found at the Clinical Center for Smell and Taste Research at Pennsylvania University that all categories (at each age) of vomen have a better sense of smell than men and also non-smokers are better than smokers. Both sexes have got the best sense of smell at the age of 30 to 60, then at the age of 60 to 80 the sense of smell looses sensitivity slowly: at the age of 80, 60 % of subjects had a very poor sense of smell and 25 % of the subjects could smell almost nothing. Thus the upper optimal limits for workplaces should be differentiated due to a) sex and b) age.

For the optimal value of $\dot{m}_{odor}$ control (maintenance) the necessary outdoor air rate can be estimated from formula

$$\dot{V} = \frac{\dot{m}_{odor}}{\varrho_{odor,opt} - \varrho_{odor,out}} = \frac{\dot{m}_{odor}}{(\dot{m}_{odor,opt}/0.008\ q_m) - \varrho_{odor}} \quad /m^3.h^{-1}/$$

where $\dot{m}_{odor}$ = the quantity of arising odor in the room $/mg.h^{-1}/$

$\dot{m}_{odor,opt}$ = optimal odor rate upper limit $/mg.h^{-1}/$

If there is no special odor agent within the room, carbon dioxide can be used as a criterion whose optimal concentration for sitting subject with light activity is

a) 0.07 % according to Pettenkofer (old classic value) with corresponding outdoor air rate 25 $m^3.h^{-1}$.person,

b) 0.10 % according to Fanger and Berg-Munch (1983) with corresponding outdoor air rate also 25 $m^3.h^{-1}$.person.

The highest admissible values of various odor agents, valid for toxic microclimate, can be the upper limit of an acceptable range; the lower limit starts at the upper limit of an optimal range.

The psychologic strain has to be respected by odor sensation ballot and odor quality ballot. They are presented (and also Yaglou s Psycho-Physical Scale) in ref.2. Of course, there must also be the relationship between optimal and acceptable values starting from physiological and psychological strain.

The problem starts if there are several odor agents within the room. Then just two possibilities may occur:

a) The odor agents do not increase the impact of each other: the greatest calculated outdoor air rate has to be used for room odor control.

b) The odor agents increase the impact of each other: the sum of calculated outdoor air rates must be used for room odor control.

REFERENCES

1. Fanger, P.O.: Introduction of the olf and decipol units to quantify air pollution perceived by humans indoors and outdoors. Energy and Buildings, Vol. 12, 1988, No.1, pp.1-6

2. Jokl, M.V.: Microenvironment: The Theory and Practice of Indoor Climate. Thomas, Illinois 1989

Table 1. Schematic Representation of the Microenvironment Evaluation

PHYSIOLOGICAL STRAIN	PSYCHOLOGICAL STRAIN
Response* of subject's physiological system: equilibrium (maybe harmony) of exposing flows between subject and environment	Response* of subject's psychologic system
with its	with its
SPECIFIC	SPECIFIC and NON-SPECIFIC
SYMPTOMS	SYMPTOMS
whose complex for each constituent forms	whose complex for each constituent forms
SPECIFIC ←**→	SPECIFIC and NON-SPECIFIC
SYNDROM	SYNDROM
which can be evaluated on the basis of	which can be evaluated on the basis of
PHYSIOLOGICAL VALUES	FEELINGS
checked by suitable	checked by suitable
MEASURING	BALLOT SYSTEM
Result: MICROENVIRONMENT LEVEL	Result: MICROENVIRONMENT QUALITY

* Depends on time, i.e. on the length of exposure

** Mutual correspondency (relationship) between physiological and psychological syndroms should be respected by every ballot system

Table 2. Optimal odor rates and optimal odor agent concentrations for a sitting subject

Odor agent	$\dot{m}_{odor,opt}$		$\rho_{odor,opt}$
	$mg.h^{-1}$	olf	$mg.m^{-3}$
Carbon Tetrachloride (Cleaning fluids, solvents, extinguishers etc.)	21.12	1	44.0000
Ammonia	16.70	1	34.8000
Chlorine	4.90	1	10.2000
Acrolein (Burning fats, switching off candels, etc.)	1.98	1	4.1300
Amylacetate (Nail varnish etc.)	2.56	1	5.3300
Pyridine (Tabacco smoke)	0.39	1	0.8100
Hydrogen Sulphide (Bad eggs etc.)	0.30	1	0.6220
Ozone	0.05	1	0.0982