Olfactory comfort assurance in enclosed spaces

Ioan Sarbu and Calin Sebarchievici

***Abstract*—** That is why the closed spaces must insure the possibility for both physical and intellectual work, as well as for some recreation activities, for rest and sleep under most favourable conditions. The achievement of these conditions depends on very many factors that decisively influence the sensation of comfort perceived, the work capacity and man's regeneration capacity. This paper approaches the indoor air quality simulation and control. It is developed a computational model for indoor air quality numerical simulation, as well a methodology to determine the outside airflow rate and to verify the indoor air quality in enclosed spaces, according to the European Standard CEN 1752. On the bases of this mathematical model there was elaborated the COMFORT 2.0 computer program, implemented on compatible microsystems IBM-PC. The COMFORT 2.0 program computes the outside airflow rate for a room ventilation, the air exchanges rate, and the variation in time of contaminants concentration of room air according to European and national norms and analyses influence of different parametres on these sizes. The performance of the developed computational model and the advantages of the proposed computer program is illustrated by using a numerical comparative application for one constructive type building.

***Keywords*—** Enclosed spaces, Olfactory comfort analysis, Outside airflow rate, Indoor air quality control, Mathematical models, Computer program, Numerical comparative analysis.

I. INTRODUCTION

REDUCING energy consumption in buildings is one of the main current directions of research in building constructions. An important part of household energy consumption is necessary to achieve, in living spaces, indoor microclimate parameters. Therefore, is particularly important the achievement of structural elements, building equipments and operating modes to allow getting both adequate comfort parameters and energy saving.

The greatest majority of people carry on 80…90% of their lives inside buildings, which must satisfy the objective and subjective requests linked to vital functions of the occupants. That is why the enclosed spaces must insure the possibility for both physical and intellectual work, as well as for some recreation activities, for rest and sleep under most favourable conditions. The achievement of these conditions depends on very many factors that decisively influence the sensation of comfort perceived, the work capacity and man's regeneration capacity. The design of the rooms must take into consideration these conditions and present tendencies to reduce the energetic consumption, that are decisively influencing the optimal or admissible values of comfort parameters. Thus the inside microclimate of a building must be the result of a computation of multicriterial optimization, taking into account technical and psychological comfort and the energy saving.

The concept of technical comfort comprises all parameters achieved and controlled with HVAC systems that act upon building occupants senses. This includes thermal, acoustic, olfactory and visual comfort. In accordance with the dissatisfied person percent of the ensured comfort: 10%, 20%, 30%, rooms are classified into three categories: A, B, C.

The perception and appreciation of basic comfort elements to man are influenced by some psychological factors, but at the same time evolution and man psychological equilibrium are closely linked with the environment. So, between psychological and technical comfort is a reciprocal connection. Human psyche depends also by other independent factors like: age, gender, etc, influencing the technical comfort level appreciation. So pleasant sensation may occur as a result of optimum technical and psychological comfort parameters (Fig. 1).

Subjective comfort of persons in a room depends on many factors: temperature, humidity and air circulation; smell and respiration; touch and touching; acoustic factors; sight and colours effect; building vibrations; special factors (solar–gain, ionization); safety factors; economic factors; unpredictable risks.

Because of some technical conditions the common influence of these factors can not be analysed, and the adaptation of the human body to a certain environment is a complex process, this one reacting to the common action of more parameters.

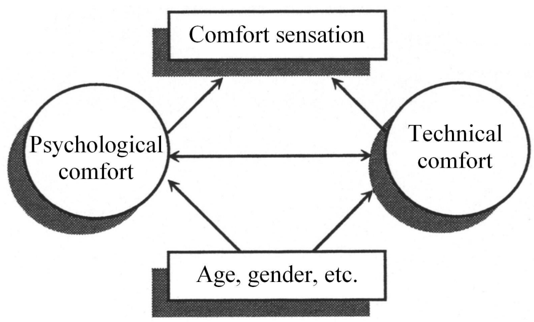

Fig. 1 Comfort sensation

Ioan Sarbu is currently a Professor and Department Head at the Building Services Department, "Politehnica" University of Timisoara, 300233 ROMANIA, e-mail address: ioan.sarbu@ct.upt.ro

Calin Sebarchievici is currently a Assistant Professor at the Building Services Department, "Politehnica" University of Timisoara, 300233 ROMANIA, e-mail address: calin.sebarchievici@ct.upt.ro

In this paper an olfactory comfort analysis in buildings is performed. It is developed a computational model for indoor air quality numerical simulation, as well a methodology to determine the outside airflow rate and to verify the indoor air quality in enclosed spaces, according to the European Standard CEN 1752. Also, it is presented the influence of carbon dioxide on human performance and productivity.

II. Olfactory Comfort

Comfort and indoor air quality (IAQ) depend on many factors, including thermal regulation, control of internal and external sources of pollutants, supply of acceptable air, occupant activities and preferences, and proper operation and maintenance of building systems. Ventilation and infiltration are only part of the acceptable indoor air quality and thermal comfort problem.

The condition to achieve human body metabolism in a enclosed space is oxygen (O_2) taking and carbon dioxide (CO_2) releasing. After respiration process air reaches the lungs through upper and lower airways. Upper airways filter the inspired air, while providing to it the proper temperature and humidity. The oxygen is transported from the lungs to tissues through blood that carry back the carbon dioxide. Expired CO_2 flow rate are illustrated in Table I.

Table I. Expired CO_2 flow rate

Activity	*M* [W/pers]	Inspired air [m^3/h]	Expired CO_2 [l/h]	Consumed O_2 [l/h]
0	1	2	3	4
Sedentary	–	0.30	12	14
Intellectual	120	0.375	15	18
Physical very easy	150	0.575	23	27
Physical easy	190	0.75	30	35
Physical hard	>270	>0.75	>30	>35

Air composition in living spaces differs from that of the outside air. Carbon dioxide concentration in outside air is between 300 and 400 ppm, and in living spaces is of about 900 ppm. The maximum admitted limit of CO_2 concentration in the inhaled air is of 1000 ppm (Pettenkofer's number). Table 2 presents the effect of different CO_2 concentrations on human body.

Table II. The effect of CO_2 concentration on human body

CO_2 concentration		Effect
[%]	[ppm]	
3	30000	Deep breathing, strong
4	40000	Head aches, pulse, dizziness, psychic emotions
5	50000	After 0.5…1 hours may cause death
8...10	80000...100000	Sudden death

Air quality is prevailingly determined by people's sensations to different odorants. Because is impossible to be measured each of the air contaminants quantitatively and qualitatively (about 8000), Fanger proposed that all these compounds to be measured by one parameter: the odor.

The odors arise in inhabited areas by the release of the human body (ammonia, methan, fatty acids), emanations of the furniture, carpets, paintings and other building materials (formaldehyde), by combustion and heating processes (carbon monoxide, fuel vapour), by exhaust gas poluted air infiltration or air from industrial areas, meal preparation, toilettes areas, mold chemical reactions, mushrooms or any decomposition products. Most of these unpleasant products are made of complex organic substance.

Excitation level in confront of some odors is very low. For example, mercaptan odor is percepted starting from a concentration of 0.00000004 mg/l. The olfactory organ main feature is adaptation. After a while, due to continuous charging, sensation of smell intensity decreases (Fig. 2).

A large number of pollutants come a time in the air with tobacco smoke. This affects the eyes, the nose and it is a risk factor for different diseases. Reduce air pollution by tobacco smoke can not be done only by increasing the air exchange rate. Thus, to annihilate the negative feelings created by smoking one cigarette are requested 100 m^3 of fresh (outside) air.

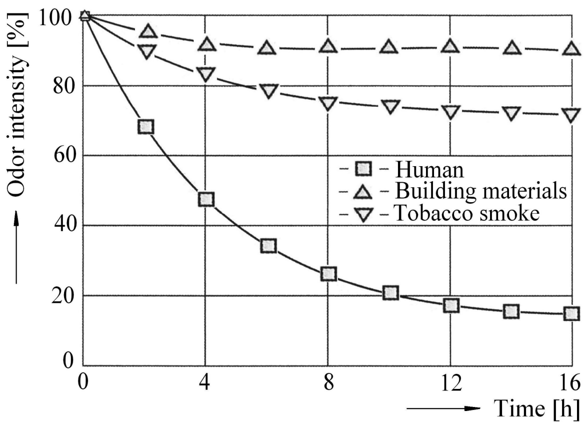

Fig. 2 Time evolution of odor intensity

Along with tobacco smoke in the air reaches carbon monoxide (CO). Maximum carbon monoxide concentration permissible values, given by international prescriptions, are 10 mg/m^3 for housing spaces and 20 mg/m^3 for kitchen and ancillary areas (3 h maximum residence time). Figure 3 illustrates the variation of CO concentration depending of smoked cigarettes number and fresh air flow–rate introduced into the room. The smoking weighty influences the CO content of expired air, whose values are indicated in Table III.

Odorant perception depends, on one side, on objective factors: concentration and toxicity of air pollutants (bio–

effluents), activity level, outside airflow rate, and on the other hand, on psychological factors with subjective character.

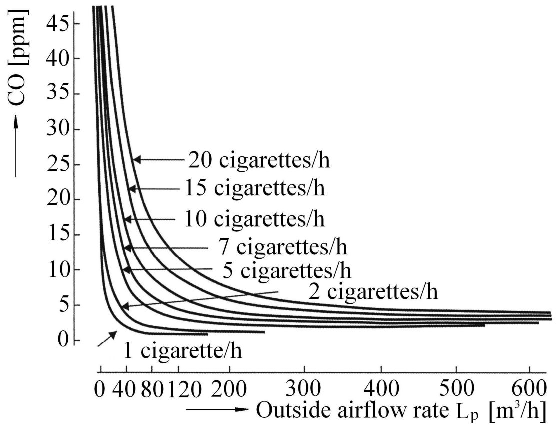

Fig. 3 Variation of CO concentration

Table III. Average values of CO concentration in expired air

No.	Category	CO concentration [mg/m^3]	
		Male	Female
0	1	2	3
1	Nonsmoker	7.1	5.8
2	Former smoker	7.8	6.5
3	Cigar and pipe smoker	9.6	12.0
4	Tobacco smoker	24.3	21.1

The relation between perceived odorant intensity and its concentration conforms to a power function [33]:

$$S = k\,C^{\beta} \qquad (1)$$

where: S is odorant intensity (magnitude); C – odorant concentration, in ppm; β – exponent of psychophysical function; k – constant characteristic of material.

In the olfactory realm: $\beta < 1.0$. Accordingly, a given percentage change in odorant concentration causes a smaller percentage change in perceived odor intensity.

Sometimes IAQ scientists cannot successfully resolve complaints about air in offices, schools, and other nonindustrial environments. Customarily, complaints are atributed to elevated pollutant concentrations; frequently, however, such high concentrations are not found, yet complaints persist.

Assuming that the inability to find a difference between air pollutant levels in buildings with registered complaints and those without complaints is due to inadequacies of prevailing measurement techniques, Fanger and other changed the focus from chemical analysis to sensory analysis [17], [18], [19]. Fanger quantified air pollution sources by comparing them with a well–known source: a sedentary person in thermal comfort. A new unit, the *olf*, was defined as the emission rate of air pollutants (bio–effluents) from a standard person. A *decipol* (*dp*) is one olf ventilated at a rate of 10 l/s of unpolluted air.

The percentage of persons dissatisfied (PPD) with air polluted by human bio–effluent (1 olf) can be calculated from the equations [19]:

$$PPD = 395\ \exp\left(-3.66 L_p^{0.36}\right) \quad \text{for } L_p \geq 0.332\ \text{l/s} \qquad (2)$$

$$PPD = 100 \quad \text{for } L_p < 0.332\ \text{l/s} \qquad (3)$$

where: L_p is the outside air flow–rate, in l/s.

The curve (Fig. 4) generated by equations (2) and (3) is based on experiments involving more than 1000 European subjects [16]. Experiments with American [6] and Japanese [24] subjects show very similar results.

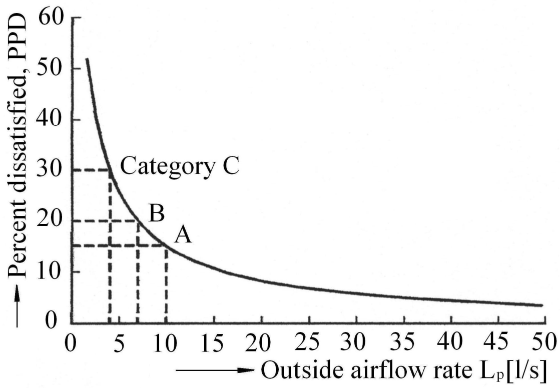

Fig. 4 PPD as a function of ventilation rate per standard person (i.e., per olf)

The idea behind the olf is to express both human and nonhuman sensory sources in a single unit: *equivalent standard persons* (i.e., in olfs). A room should therefore be ventilated to handle the total sensory load from persons and building. Table IV shows the sensory loads from different poluation sources used in CEN [7].

The sensory load on the air in a space can be determined from Figure 4 by measuring the outside air flow–rate and determining the percent dissatisfied, using an untrained panel with a minimum of 20 impartial persons [22]. The required outside air flow–rate depends on the desired percentage of occupant satisfaction.

Table IV. Sensory pollution load from different pollution sources

No.	Source	Sensory load
0	1	2
1	Sedentary person (1…1.5 met)	1 olf
2	Person exercising low level (3 met)	4 olf
3	Person exercising medium level (3 met)	10 olf
4	Children, kindergarten (3…6 yrs)	1.2 olf
5	Children, school (4… 16 yrs)	1.3 olf
6	Low–polluting building	0.1 olf/m^2
7	Non–low–polluting building	0.2 olf/m^2

Various factors make odor control an important consideration in ventilation engineering:

– contemporary construction methods result in buildings that allow less air infiltration through the building envelope;

– indoor sources of odors associated with modern building materials, furnishings, and office equipment have increased;

– outdoor air is often polluted;

– energy costs encourage lower ventilation rates at a time when requirements for a relatively odor–free environment are greater than ever.

Outdoor air requirement for acceptable indoor air quality have long been debated. Historically, the major considerations have included the amount of outdoor air required to control moisture, carbon dioxide and tobacco smoke generated by occupants. These considerations have led to prescriptions of a minimum rate of outdoor air supply per occupant.

Tables V and VI present the minimum rate of outside airflow per occupant for different activities, according to European Standard CEN 1752, that also takes into consideration the smokers in ventilated rooms.

Table V. Minimum rate of outside airflow

No	Activity	Outside airflow rate [$m^3/(h\cdot pers)$]
0	1	2
1	Intellectual	30
2	Physical very easy	30
3	Physical easy	40
4	Physical hard	50

Table VI. Minimum rate of outside airflow for rooms with smokers

Room category	Outside airflow rate [$m^3/(h\cdot pers)$]			
	Without smokers	20% smokers	40% smokers	100% smokers
0	1	2	3	4
A	36.0	72.0	108.0	108.0
B	25.2	50.4	75.6	75.6
C	14.4	28.8	43.2	43.2

The perceived olfactory sensation depends not only on the pollutant source but also to a great extend, on the dilution degree with outside air.

The olfactory pollution degree of a room is given by:

$$C_i = C_p + \frac{10G}{L_p} \quad (4)$$

where: C_i is the indoor air quality, in dp; C_p – outdoor air quality, in dp; G – contaminants concentration of room air.

III. Indor Air Quality Simulation Model

A. General Equation for the Time Evolution of a Contaminant Concentration

Consider a single zone compartment, where there is a source of pollution that has gas exchanges with the outside air, and where an air purifier may be used. Admitting the possibility of deposition and absorption of the pollutant on the walls and other surfaces, the temporal evolution of the concentration of a pollutant is modeled by the following differential equation [20]:

$$\frac{\mathrm{d}c}{\mathrm{d}\tau} = \frac{P}{V} + nc_p - nc - \nu_d \frac{S}{c} - \frac{L_p}{V} c\,\varepsilon_p \quad (5)$$

in which: c is the instantanous average contaminant concentration, in mg/m^3; P – pollutant generation inside the compartment, in mg/h; V – room volume, in m^3; n – air exchange rate, in h^{-1}, i.e., the fresh air flowrate divided by the room volume; c_p – concentration of the contaminant in outside air, in mg/m^3; ν_d – deposition rate of pollutant, in $mg/(h\cdot m^2)$; S – surface of deposition, in m^2; L_p – flow rate through the air purifier, in m^3/h; ε_p – efficiency of the air purifier.

The effects of absorption or deposition of the pollutant inside the compartment and the removal of filtering through the air purifier system may be considered in a simplified form, reducing the intensity of the sources of their value to them. Thus, for purposes or simplification, their terms in the equation may be despised, coming:

$$\frac{\mathrm{d}c}{\mathrm{d}\tau} = \frac{P}{V} + nc_p - nc(\tau) \quad (6)$$

That, integrated for a situation where V, P, c_p, L_p remain constant, since an initial time instant $\tau = 0$, where the initial concentration $c_0 = c_p$, till a generic time instant τ will come:

$$c(\tau) = c_{eq} + \left(c_0 - c_{eq}\right)\cdot e^{-n} \quad (7)$$

in which c_{eq} is the equilibrium concentration.

B. Equilibrium concentration

The equilibrium concentration c_{eq}, in the equation (7), is the value that occurs when it ceases the variation in concentration. Thus, it is obtained equalizing the first member of equation (6) to zero, which gives:

$$c_{eq} = c_p + \frac{P}{Vn} \quad (8)$$

that as $n = L_p/V$, comes:

$$c_{eq} = c_p + \frac{P}{L_p} \quad (9)$$

The equations are solved numerically. The outputs of the simulation are instantaneous concentration of the pollutant and the graphical results of the time–evolution of the pollutant concentration.

C. Metabolic CO_2 computation

In recent study [15], the expressions to calculate the volumes of oxygen (O_2) and carbon dioxide (CO_2) in the human respiration process are given, as a function of the metabolic rate and the corpulence of the studied person. The volume of consumed O_2 is given by:

$$V_{O2} = \frac{0.00276 A_D M}{0.23r + 0.77}\frac{1}{S} \quad (10)$$

where:

$$A_D = 0.202\, m^{0.425} h^{0.725} \quad (11)$$

in which: A_D is the nude body surface area [12], in m^2; M – metabolic rate, in met (1 met = 58.15 W/m^2); r – ratio between the volume of released CO_2 and the consumed volume of O_2.; m – mass of human body, in kg; h – height of human body, in m.

The ratio *r* usually takes the value of 0.83, but that may vary till 1, for a person with a very high metabolic rate (more than 5 met).

Once the volume of O_2 has been calculated, the volume of released CO_2, for normal metabolic rate cases is computed from:

$$V_{CO2} = 0.83 \times V_{O2} \tag{12}$$

In [20] is presented a software tool for indoor air quality simulation.

Typical values of pollutants usually checked in IAQ audits and released by one cigaratte burning are given in Table VII, which summarizes information collected in [9], [35].

Table VII. Typical emission from a smoked cigarette

Type	Pollutant	Unit [mg]
0	1	2
Particle	Particles suspended in air	18
Chemical	Carbon dioxide (CO_2)	160…550
	Carbon monoxide (CO)	60
	Formaldehyde (HCHO)	0.4
	Total volatile organic compunds (VOC)	3.6

IV. Computation of Outside Flow–Rate and Indoor Air Quality Control

A. Mathematical model

Computation of outside air flow–rate in a room can be performed function of:

- number of occupants, keeping CO_2 concentration under the maximum admitted level (according to Romanian Norm I 5);
- number of occupants and room surface (according to German Norm, DIN 1946);
- indoor air quality (according to European Standard CEN 1752, described below).

Ventilation efficiency ε_v is a criterion for energy and fan performances. This is used to evaluate a ventilation system and is defined by following expression:

$$\varepsilon_v = \frac{c_i - c_p}{c_{zl} - c_p} \tag{13}$$

where: c_i is the contaminants concentration in the exhausted air; c_p – contaminants concentration the supply outside air; c_{zl} – contaminants concentration in the working area.

The value of ε_v depends on the entrance place and the exhaust way of outside air, and on the difference between the outside air temperature t_e and indoor air temperature t_i (Table VIII).

The outside air flow–rate L_p, in l/s, can be computed function of IAQ from equation:

$$L_p = 10 \frac{G}{(C_i - C_p)\varepsilon_v} \tag{14}$$

where:

$$G = G_{oc} + G_{ob} \tag{15}$$

in which: G is the contaminants concentration of room air, in olf; C_i – indoor air quality, in dp (Table IX); C_p – outside air quality, in dp (Table X); G_{oc} – contaminants quantity from the occupants (Table XI); G_{ob} – contaminants quantity from room objects (building elements, furniture, carpets, etc.) ha-ving the values in Table XII.

Table VIII. Ventilation efficiency, ε_v

System type	t_e–t_i [°C]	ε_v
0	1	2
up–up	<0	0.9…1.0
	0…2	0.9
	2…5	0.8
	>5	0.4…0.7
up–down	<–5	0.9
	–5…0	0.9…1.0
	>0	1.0
down–up	<0	1.2…1.4
	0…2	0.7…0.9
	>2	0.2…0.7

Table IX. Indoor air quality, C_i

Room category	C_i [dp]	Percent dissatisfied [%]
A	1.0	15
B	1.4	20
C	2.5	30

Table X. Outside air quality, C_p

No.	Air source	C, [dp]
0	1	2
1	Mountain, sea	0.05
2	Locality, fresh air	0.1
3	Locality, mean air	0.2
4	Locality, polluted air	0.5

The outside air flow–rate L_p, in m^3/h, can be computed and function of hygienic sanitary conditions follow as:

$$L_p = \frac{P}{(c_{i\max} - c_{p\max})\varepsilon_v} \tag{16}$$

where: P is the power of the indoor pollutant source, in mg/h; $c_{i\max}$ – maximum admitted concentration of the most critical contaminant of room air, in mg/m^3; $c_{p\max}$ – maximum admitted concentration of the most critical contaminant of outside air, in mg/m^3.

Table XI. Contaminants quantity from the occupants, G_{oc}

No.	Contaminants source	G_{oc} [olf/pers]
0	1	2
1	Adults resting, if the percentage of smokers is:	
	0 %	1
	20 %	2
	40 %	3
	100 %	6
2	Adults, if metabolic rate is:	
	reduced (3 met)	4
	medium (6 met)	10
	high (10 met)	20
3	Children:	
	children under school age (2.7 met)	1.2
	pupils (1…1.2 met)	1.3

Table XII. Contaminants quantity from room objects, G_{ob}

No.	Building destination	G_{ob} [olf/m^2]
0	1	2
1	Offices	0.02…0.95
2	Schools	0.12…0.54
3	Kindergarten	0.20…0.74
4	Meeting rooms	0.13…1.32
5	Houses	0.05…0.10

To determine the time evolution of the contaminants concentration c_i in indoor air two hypotheses are assumed:

– constant pollution in time, where the balance equation within an infinitesimal time interval $d\tau$ is:

$$L_p c_p d\tau + P d\tau - L_p c_i d\tau = V dc_i \qquad (17)$$

where V is the room volume.

Integrating the equation (17), with the initial condition $c_i = c_p$, for $\tau = 0$, we obtain:

$$c_i = c_p + \frac{P}{L_p}\left(1 - e^{-n\tau}\right) \qquad (18)$$

where n is the air exchange rate.

– instantaneous pollution at moment $\tau = 0$; consequently, the contaminant initial concentration is given by the equation:

$$c_o = \frac{P}{V} \qquad (19)$$

The balance equation for an infinitesimal time interval $d\tau$ is:

$$L_p c_p d\tau - L_p c_i d\tau = V dc_i \qquad (20)$$

Integrating equation (20) with the initial condition $c_i = c_o$, for $\tau = 0$, is obtained following expression:

$$c_i = c_p - c_o e^{-n\tau} \qquad (21)$$

B. Computer Program COMFORT 2.0

The computer program COMFORT 2.0 allows to determine the outside air flow–rate and air exchange rate for the ventilation of a room and the variation in time of contaminants concentration of room air both on the basis of the mathematical model described above and on some national norms (I5, DIN 1946), as well as to analyse the influence of different parameters on these characteristics.

- The inputs data are: geometrical characteristics of the room, in m; number of occupants; activity type; room category; outside air quality, in dp; ventilation system type; ventilation efficiency; smokers existence in room.
- The results of program are the following: outside air flow–rate; air exchange rate; polluting substances of indoor air; time variation of CO_2 concentration from room air.

C. Numerical Application

It is considered an A category room with geometrical dimensions 10×10×2.7 m, where there are 11 persons having an intellectual activity, and smoking is forbidden. Production rate of CO_2 for the occupants is of 15 l/(h·pers) and CO_2 concentration in outdoor air has the value of 350 ppm. The floor finishing is made of parquet floor or PVC.

A comparative study for computation of outside air flow–rate and indoor air quality control according to the European Standard CEN and national norm I and DIN is performed using the computer program COMFORT 2.0.

The values obtained for the outside air flow–rate and the air exchange rate are reported in Table XIII.

Table XIII. Outside air flow–rate L_p and air exchange rate, n

Computation norm	Method	L_p [m^3/h]	n [h^{-1}]
0	1	2	3
CEN 1752	Air quality – parquet floor	2306	8.54
	Air quality – PVC floor	8494	31.46
I5	Number of occupants	330	1.22
DIN 1946	Surface of the room	600	2.22
	Number of occupants	660	2.44

In Figure 5 is represented the variation of outside air flow–rate function of the indoor and outdoor air quality. Figure 6 shows the time variation of CO_2 concentration in room air.

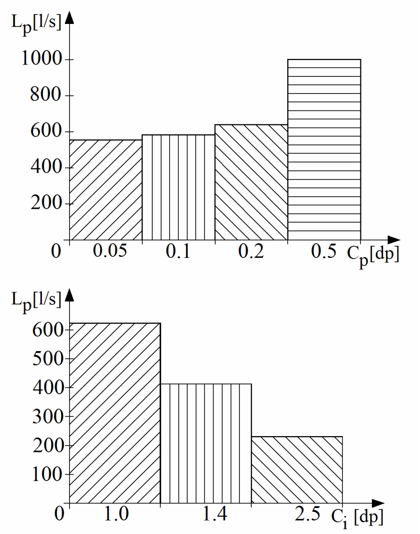

Fig. 5 Variation of outside air flow–rate function of outdoor and indoor air quality

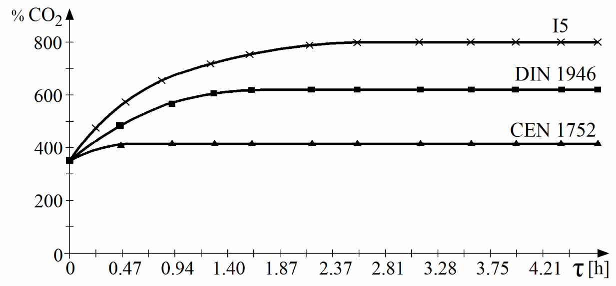

Fig. 6 Time variation of CO_2 concentration

From Table XIII it is to be seen that the outside air flow–rate computed according to norm I5 has the smallest value, leading to the highest values of CO_2 concentration of room air. This CO_2 concentration determines a state of strong tiredness and head aches for the occupants.

V. Influence of Carbon Dioxide on Human Performance and Productivity

Interdisciplinary efforts in the last decade of many researches converge to the necesity to find and develop the “resources” for achieving optimal environment conditions.

Although there are many weaknesses and divergents in the knowledge of environment effects on productivity and health activities, one thing is universally recognized, namely the obligativity of keeping the comfort parameters: temperature, humidity, sound level, indoor air quality, air velocity, etc. That is why VAC specialists must convince that positive effects of air–conditioning are much larger and important than negative ones.

Temperature influence is decisive both in terms of comfort and productivity.

Another cause that causes discomfort associated with interior temperatures beyond the comfort limit is the dioxide carbon concentration. Manifestation of this discomfort is characteristic to densely populated rooms: theatrical and meeting rooms, public buildings (bank lobbies, counter rooms etc.), and especially to rooms from education buildings. Classrooms are usually densely populated and the length of stay is at least four hours.

It is considered that air is contaminated when the content of carbon dioxide ranges between 0.1 and 0.15%, which corresponds for a concentration of 1000 ppm and 1500 ppm. Becomes harmful to the body starting from a concentration of 2.5%. Normal air contents corbon dioxide in ranges of 0.032% and 0.035%, reaching 0.04% in urban centers.

Measurements of carbon dioxide concentration in a natural ventilated classroom through leaks had shown that in 10…15 minutes the concentration reaches values over 1000 ppm, and after 45 minutes values to 2500 ppm.

The sedentary human body approximatively releases 15 l/h of carbon dioxide. For not exceeding the maximum concentration it is has to be assured a fresh airflow rate L_p for each person:

$$L_p = \frac{Q}{c_{i\,\max} - c_{p\,\max}} = \frac{15000}{1500-400} = 12.5\ \mathrm{m^3/(h \cdot pers)} \quad (22)$$

in which: Q is the CO_2 emission of human body, in cm^3/h; $c_{i\max}$ – maximum admitted CO_2 concentration for indoor air, in ppm; $c_{p\ \max}$ – maximum admitted CO_2 concentration for outside (fresh) air, in ppm.

This airflow rate can not be assured with a natural ventilation through leaks. For rooms with these destinations, the simple windows opening (intense natural ventilation) can not satisfy, because in winter time only in break time will partly solve the reduction of carbon dioxide. In summer time, even if the windows can be opened, comes out the growth temperature and noise intesity inconvenience.

In Figure 7 is represented in a nomogram the outside air flow–rate depending by maximum admitted CO_2 concentration.

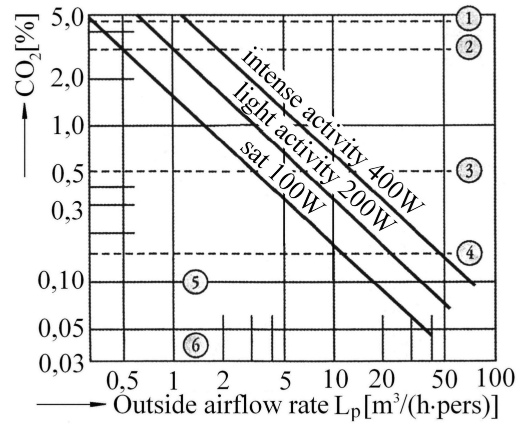

Fig. 7 Outside airflow rate depending by admitted CO_2 concentration
1-expired air; 2-underground rooms; 3-industrie maximum concentration; 4-offices maximum concentration; 5-Pettenkofer’s number; 6-outdoor air

Taking into account the overlapping of contaminant, an insanitary environment, correlated with a high temperature reduces even more the human productivity.

Even if only in these two aspects (temperature and CO_2 concentration) the VAC specialists have the duty to convince over the need to assure these two parameters by using air–conditioning systems.

VI. Conclusions

Computer model developed offer the possibility of detailed analyses on olfactory comfort in enclosed spaces, being of a real use for the design and research activity and in the environmental studies.

Results show that the microclimate in rooms influence not only the comfort but also the health of the occupants, and preserving the comfort parameters at the optimal values is the mission of the engineer for designing and operating of HVAC systems.

The indoor environment is influenced by the way the equipments are designed, produced and operated. That is why it is necessary to decide upon the equipments that are able to give the proper microclimate conditions, permanently observing the elimination of all secondary effects (professional illnesses) that have negative influences upon human health.

It is possible at the design stage of HVAC systems and buildings to take into account most of the comfort criteria.

References

[1] ASHRAE, *Thermal Environmental Conditions for Human Occupancy* – ANSI/ASHRAE Standard 55/2004, American Society of Heating, Refrigerating and Air Conditioning Engineers, Atlanta, 2004.

[2] ASHRAE, *Fundamentals Handbook*, American Society of Heating, Refrigerating and Air Conditioning Engineers, Atlanta, 2009.

[3] L. Bánhidi and L. Kajtár, *Komfortelmélet*, Műegyetemi Kiadó, Budapest, 2000.

[4] L. Bánhidi, L. Garbai and I. Bartal, Research on static and dynamic heat balance of the human body, *WSEAS Transactions on Heat and Mass Transfer*, no. 3, vol. 3, 2008, pp. 187-197.

[5] M. Baritz, L. Cristea, D. Cotoros and I. Balcu, Thermal human body behavior analyze during cycling mouvements, *Proceedings of the WSEAS Int. Conference on Heat Transfer*, THE'08, Rhodes, Geece, August 20-22, 2008.

[6] W.S. Cain, et al. Ventilation requirements in buildings – I: Control of occupancy odor and tobacco smoke odor, *Atmosferic Environment*, vol. 17, 1983, pp. 1183-1197.

[7] CEN, *Ventilation for buildings. Design criteria for the indoor environment*, Technical Report CR 1752, European Committee for Standardization, Brussels, 1998.

[8] CEN EN15251, *Indoor environmental input parameters for design and assessment of energy performance of buildins – addressing indoor air quality, thermal environment, lighting and acoustics*, 2006.

[9] S. Charles, et al. VOC and particles emissions from commercial cigarettes: Analysis of 2.5 DMF as an ETS tracer, *Environmental Science and Technology*, vol. 42, 2008, pp. 1324-1331.

[10] G. Clausen, P.O. Fanger, W.S. Cain and B.P. Leaderer, The influence of aging particele filtration and humidity on tobacco smoke odour, *Proceedings of CLIMA 2000*, Copenhagen, vol. 4, 1985, pp. 345-349.

[11] DIN, *Raumlufttechnik; Gesundheitstechnische Anforderungen*, VDI–Lüftungsregeln, DIN Standard 1946-2, Deutsches Institut für Normung, Berlin, 1994.

[12] D. DuBois and E.F. DuBois, A formula to estimate approximate surface area, if height and weight are known, *Archives of Internal Medicine*, no. 17, 1916, pp.863-871.

[13] ECA, *Guideline for ventilation requirements in buildings*, European Collaborative Action Indoor Air Quality and its Impact on Man: Report 11, EUR 14449 EN, Office for Official Publications of the European Committees, Luxemburg, 1992.

[14] L.E. Ekberg, Outdoor air contaminants and indoor air quality under transient conditions, *Indoor Air*, vol. 4, 1994, pp. 189-196.

[15] S.J. Emmerich and A.K. Persily, *State of the Art Review of CO_2 Demand Controlled Ventilation Technology and Application*, NISTIR 6729, National Institute of Standards and Technology, USA, 2001.

[16] P.O. Fanger and B. Berg–Munch, Ventilation and body odor, *Proceedings of Engineering Foundation Conference on Management of Atmospheres in Tightly Enclosed Spaces*, ASHRAE, 1983, pp. 45-50.

[17] P.O. Fanger, A solution to the sick building mystery, *Proceedings of the International Conference on Indoor Air and Climate*, Institute of Water, Soil and Air Hygiene, Berlin, 1987.

[18] P.O. Fanger, Introduction of the olf and decipol units to quantify air pollution perceived by humans indoors and outdoors, *Energy and Buildings*, vol. 12, 1988, pp. 1-6.

[19] P.O. Fanger, J. Lauridsen, P. Bluyssen and G. Clausen, Air pollution sources in offices and assembly halls quantified by the olf unit, *Energy and Buildings*, 12, 1988, pp. 7-19.

[20] M. Gameiro da Silva, Indoor air quality simulation tool, *Rehva Journal*, vol. 46, no. 4, 2009, pp. 30-32.

[21] D.F. Geary, New guidelines on Legionella, *ASHRAE Journal*, vol. 44, no. 9, 2000, pp. 44-49.

[22] L. Gunnarsen and P.O. Fanger, Adaptation to indoor air pollution, *Energy and Buildings*, vol. 18, 1992, pp. 43-54.

[23] I5 normative – *Design and execution of VAC systems*, (in Romanian), Publishing House Impuls, Bucharest, 1998.

[24] G. Iwashita, K. Kimura, S. Tanabe, S. Yoshizawa and K. Ikeda, Indoor air quality assessment based on human olfactory sensation, *Journal of Architecture, Planning and Environmental Engineering*, vol 410, 1990, pp. 9-19.

[25] L. Kajtár, T. Hrustinszky, Investigation and influence of indoor air quality on energy demand of office buildings, *WSEAS Transaction on Heat and Mass Transfer*, no. 4, vol. 3, 2008, pp. 219-228.

[26] H.N. Knudsen, O. Valbjorn and P.A. Nielsen, Determination of exposusire–response relationship for emissions from building products, *Indoor Air*, vol. 8, no. 4, 1998, pp. 264-275.

[27] L. Molhave and M. Thorsen, A model for investigations of ventilation systems as sources for volatile organic compunds in indoor climate, *Atmospheric Environment*, vol. 25A, 1990, pp. 241-249.

[28] B.W. Olesen, A simplified calculation method for checking the indoor climate, *ASHRAE Transactions*, vol. 98, Part 2, 1983.

[29] J.M. Samet, M.C. Marbury and J.D. Spengler, Healt effects and sources of indoor air pollution, *American Review of Respiratory Disease*, vol. 136, 1987, pp. 1486-1508.

[30] I. Sârbu and F. Kalmár, *Energetical optimization of buildings* (*in Romanian*), Publishing House Matrix Rom, Bucharest, 2002.

[31] I. Sârbu, F. Kalmár and L. Kardos, Fundamental components of the comfort, *Proceedings of the 11th Conference „Building Services and Energy Saving*", Iasi, Romania, July 5-6, 2001, pp.84-93.

[32] I. Sârbu and O. Bancea, Analysis of thermal and olfactory comfort in closed spaces, *WSEAS Transaction on Heat and Mass Transfer*, no. 3, vol. 4, 2009, p.65-74.

[33] S.S. Stevens, On the psychophysical law, *Psychological Review*, vol. 64, 1957, pp. 153.

[34] M. Su, Q. Chen and C.M. Chiang, Comparison of different subgridscale models of large eddy simulation for indoor airflow modeling, *Journal of Fluid Engineering*, vol. 123, 2001, pp. 628-639.

[35] * * * Ventilation and Smoking, *Rehva Guide Book*, no. 4, 2004.