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Computer modeling and simulation of carbon dioxide indoor concentration

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Summary

Indoor pollutant concentration is more significant for human health than the outdoor atmosphere because people spend most of their time in buildings. There is pollutant concentration enhancement, relative humidity, mould reproduction and rise of environment not corresponding to human organism needs because of insufficient ventilation. Indoor air quality depends on many factors. Carbon dioxide is the most important indoor pollutant whether the pollutant source is presented only by people. There is overview of software enabling carbon dioxide modeling and simulation and also program CONTAM 2.4 using in my paper. It means multizone modeling where at the single zone is obtained carbon dioxide concentration thanks to geometry, openings, ventilation and pollutant sources interpolation. There were chosen three spaces for simulation of occupied flat. The results show that CO2 concentration run is similar to interior occupation. Increasing time of concentration to constant value and decreasing time of concentration to ventilation air concentration depend on room volume.

KEYWORDS: indoor air quality, computer modeling and simulation, carbon dioxide

1. INTRODUCTION

The aim for thermal losses lowing directed to limiting natural ventilation by windows. Tight windows have insufficient infiltration. They are unsuitable from the hygienic point of view. It leads to pollutant concentration enhancement relative humidity, mould reproduction and rise of environment not corresponding to human organism. So it is necessary to ensure sufficient mechanical ventilation.

In spite of minimal ventilation, the poor window sealing of old windows ensured sufficient ventilation rate, but it led to higher thermal losses. The residential space ventilation should ensure taking away of the depleted air, pollutants, moisture and smell to ensure the pleasant microclimate in rooms.

ISSN 1582-3024

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Sufficient ventilation is important for a construction itself as well. High relative humidity can cause water vapors condensation in colder places – thermal bridges – and thereby increase mould rise risk.

2. ANALYSIS

2.1. Indoor air quality

Indoor air quality depends on many factors, especially on: outdoor air quality, air amount per person or ventilation rate, ventilation plant, amount of air pollutants, that sources are: inhabitants and their metabolism, inhabitants' activities, construction materials, social settlement, flat cleaning and housekeeping. Pollutants influencing indoor air quality are: carbon dioxide CO2, carbon monoxide CO, nitrogen oxides NOx, sulfur oxides SOx, formaldehyde, VOC, asbestos, dust, ozone, hydrocarbons, odors, radon, relative humidity, acaridae and microorganisms. Microorganisms are able to reproduce and multiply their negative influence on inhabitants' health during certain indoor conditions. Some of the chemical compounds presented in the indoor air belong among potential or evident human carcinogens.

Classic Pettenkofer normative 25 m3.h-1 per person is based on the request to abolish unpleasant body odor evoking strain of depleted air by adhering carbon dioxide concentration 700 ppm. Pettenkofer normative is still a basic value for standards of most developed states. ASHRAE standard is based on it as well.

Table 1. Software for indoor environment modeling and simulation

Name	**IDA Indoor Climate and Energy**
Characteristic	a tool for simulation of thermal comfort, indoor air quality and energy consumption in buildings
Inputs	building geometry, thermal characteristics, internal loads and schedules, heating and cooling equipment and system characteristics
Results	zone heat balance, including specific contributions (sun, occupants, equipment, lights), ventilation, heating, cooling, surface transmissions, air leakage, cold bridges and furniture, solar influx, air CO2 and moisture levels, air and surface temperatures, comfort indices, PPD and PMV
Name	**IAQ-Tools**
Characteristic	indoor air quality analysis including troubleshooting "sick" buildings, ventilation and filter design, design for contaminant source control, only simple-zone modeling
Inputs	filter effectivnes, air amount, pollutant production, indoor and outdoor pollutant concentration, contaminants: airborne solid contaminants (asbestos, lead, and particulates), gases (ammonia,

	carbon dioxide, carbon monoxide, ethane, formaldehyde, hydrogen sulfide, methane, nitrogen oxides, ozone, propane, radon, and sulfur dioxide), bioaerosols (bacteria, fungi, and molds), tracer gases
Name	**COMIS**
Characteristic	air flow distribution model for multizone structures; takes wind, stack and HVAC into account; allows for crack flow, flow through large openings, and single-sided ventilation
Inputs	air-flow network, operating schedule, weather data, pollutant sources
Results	available graphical
Availability	http://www-epb.lbl.gov/comis
Name	**BSim2002**
Characteristic	indoor climate and energy conditions, design heating, cooling and ventilation plants, the geometry of the rooms created in the model graphic editor or imported from CAD drawings, room or rooms are attached to thermal zones by drag and drop in the tree structure of the model BSim 2002 includes standard libraries for: constructions, materials, glass, window frames, people loads, schedules, the user can define new
Inputs	climate data, constructions and materials, heating, cooling, internal loads, moisture load, ventilation systems, automatic control strategies
Results	available weekly, monthly or periodical basis, in tabular or graphic form
Name	**CONTAM 2.4**
Characteristic	multizone indoor air quality analysis and ventilation, flowing among particular rooms during natural, hybrid and mechanical ventilation, wind pressure on building facade
Inputs	the quantity airflow and pollutant production, schedules, outdoor pollutant concentration, geometry of zones, ventilation
Results	pollutant concentration, airflow – infiltration, exfiltration, flowing among particular rooms
Availability	http://www.bfrl.nist.gov/IAQanalysis/CONTAMWdesc.htm

2.2. What pollutant is the most critical?

Pollutant production generating indoor as a result of people presence is possible to describe physically and to model. The shortness of the air oxygen, whose consumption is also possible to describe physically, can have the negative influence on indoor environment as well. Air amount is 1,06 m3.h-1 per person for the minimal O2 concentration, 8,38 – 9,96 m3.h-1 per person for the optimal relative humidity and 22,5 m3.h-1 per person for the acceptable CO2 concentration. The highest amount of ventilation air is necessary for the acceptable CO2 compliance concentration.

2.3. Carbon dioxide

Carbon dioxide is the most usual air pollutant. Human metabolism, respiration and thermoregulation are the main sources of this pollutant. Respiration is adversely influenced by higher carbon dioxide concentration - already above 15 000 ppm. If its concentration in indoor air enhances above 30 000 ppm, most of people will have headache and dizziness. Concentration above 60 000 – 80 000 ppm leads to lethargy and losing consciousness. According to Czech Government order 178/2001 Sb. maximum acceptable CO2 concentration is 25 020 ppm [5].

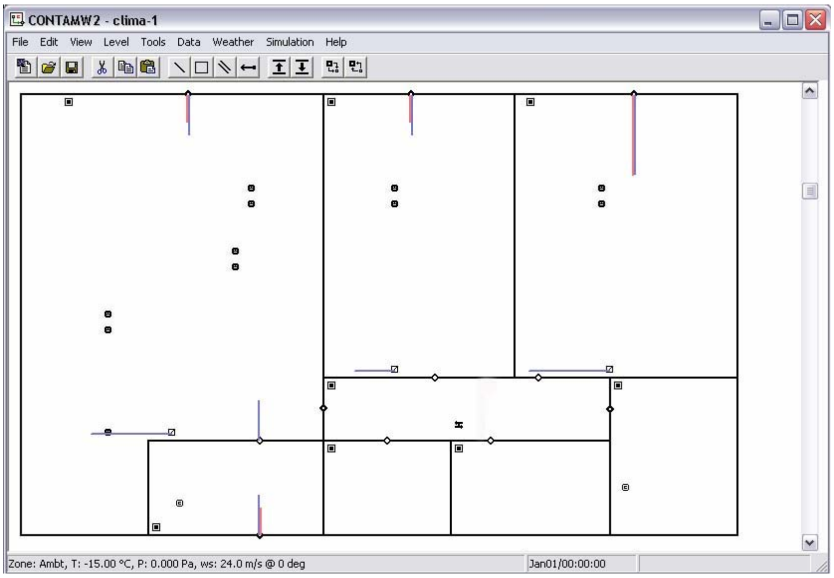

Figure 1. The plan of observed flat

2.4. Software for indoor environment modeling and simulation

Software for indoor air quality modeling and simulation are described in Table 1. There are described main characteristics, inputs and results, if the program is multi-zone or simple-zone.

3. METHOD - MATHEMATICAL MODEL IN PROGRAM CONTAM 2.4

There were chosen three alternatives for simulation of occupied flat. Alternative no. 1 presents flat occupation during weekday, e.g. when mother and her child are at home all the day and father is at work.

Alternative no. 2 presents weekend, when all family is at home.

Alternative no. 3 describes weekday whit visit in the evening. The plan of the observed flat shows Figure 1.

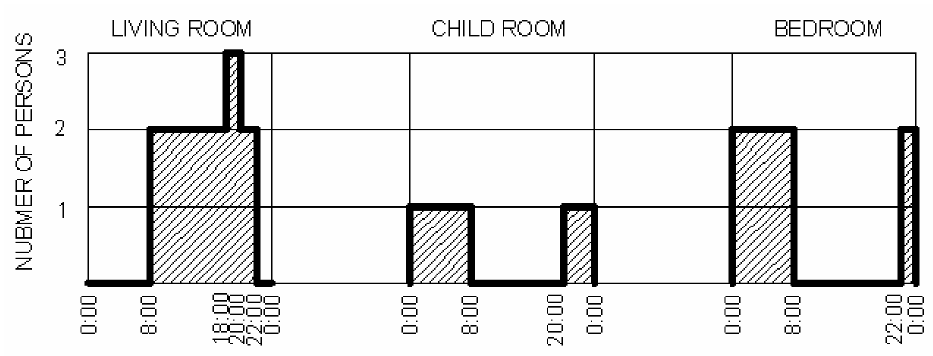

Figure 2. Particular zone occupation for alternative no. 1

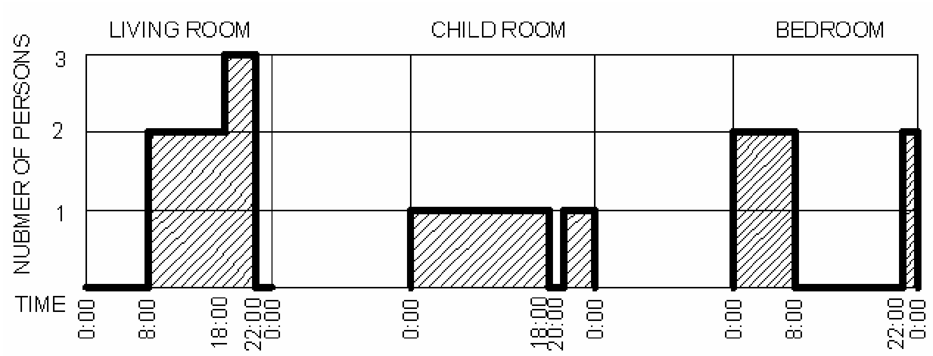

Figure 3. Particular zone occupation for alternative no. 2

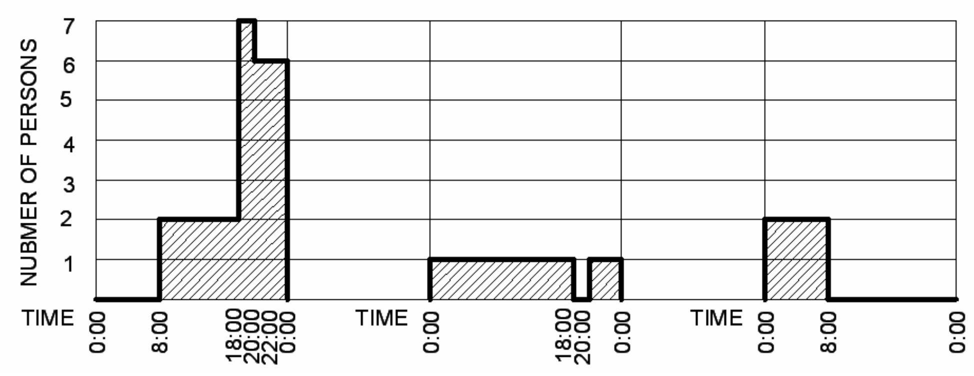

Figure 4. Particular zone occupation for alternative no. 3

ISSN 1582-3024

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The observed rooms were presented by a living room and a bedroom, their occupation is stated in Figures 2, 3 and 4.

The detected indoor pollutant is carbon dioxide. It was counted with outdoor carbon dioxide concentration 350 ppm and respiration production 19 $l.h^{-1}$ per person. Ventilation air amount for particular spaces is stated in Table 2.

Table 2. Ventilation air amount

Zone (room)	Ventilation air amount		
		[$m^3.h^{-1}$]	[$m^3.h^{-1}$ per person]
Living room	Alternative no. 1 and 2 Alternative no. 3	68 155	22,5
Child room		22,5	22,5
Bedroom		45	22,5

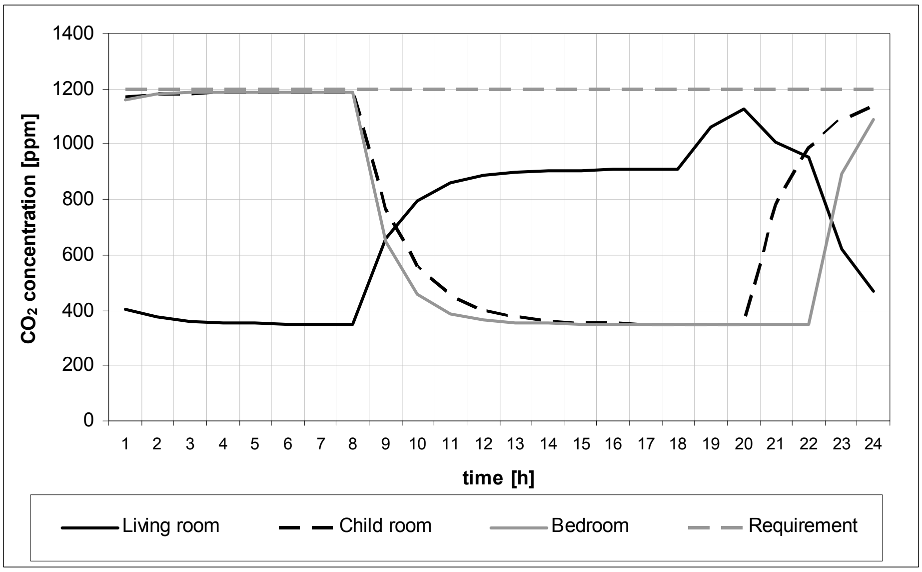

Figure 5. Carbon dioxide concentration runs for alternative no. 1

4. RESULTS

The carbon dioxide concentration in particular rooms was calculated by program CONTAM 2.4. Figures 5, 6 and 7 show carbon dioxide concentration runs. The results show, that CO_2 concentration run is similar to interior occupation, increasing time of concentration to constant value and decreasing time of concentration to ventilation air concentration depend on room volume. From

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concentration runs is distinct, that ventilation air amount 22,5 $m^3.h^{-1}$ per person is the necessary air amount for ensuring maximal carbon dioxide concentration 1200 ppm according to EN CR 1752 for Class "C".

Figure 6. Carbon dioxide concentration runs for alternative no. 2

Figure 7. Carbon dioxide concentration runs for alternative no. 3

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5. DISCUSSION

The concentration dependence of CO_2 on supplied air amount for alternative no. 3 shows Figure 7. The maximum CO_2 concentration is 1200 ppm at supply 155 $m^3.h^{-1}$, it is much higher than in previous alternatives, and this is only for case of a visit. If it would be 68, maximal carbon dioxide concentration will be 2000 ppm for four hours. There is a question, if the short-term exceeding of concentration has an effect for ventilation design. During steady-state air return with more people than expected in the interior causes higher pollutants production. The constant return air volume increases energy losses if the room is empty. The ideal solution is while CO_2 sensor is in each room and air amount is controlled by actual demand.

6. CONCLUSIONS

It was documented that CO_2 concentration is the critical criterion for ventilation air amount design. The results show, that CO_2 concentration runs is similar to interior occupation. Simulation in program Contamw 2.0 showed, that necessary air amount per person for ensuring maximal CO_2 concentration 1200 ppm is 22,5 $m^3.h^{-1}$ per person. It was established that, Pettenkofer normativ 25 $m^3.h^{-1}$ per person is valid.

Acknowledgements

This paper presented results supported by Research Plan CEZ MSM 6840770005.

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ISSN 1582-3024