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METHODOLOGY FOR EVALUATION OF VENTILATION EFFICIENCY IN ROOMS CONSIDERING THE CO_2 LOADING

Основною метою цього дослідження є вивчення впливу температури повітря в приміщенні, вологості і концентрації CO_2 на поведінку людини в двох різних зонах: в зоні з природною вентиляцією, тобто без вентиляційного устаткування, та в зоні з примусовою вентиляцією, тобто з вентиляційним устаткуванням чи обладнанням для кондиціонування повітря.

Ключові слова: температура повітря всередині приміщення, вологість, кондиціонер.

The main purpose of this research is investigation of influence of the indoor air temperature, humidity and CO_2 concentration on a human behaviour in the two different areas: in the area with natural ventilation, i.e. without ventilation equipment and in the second area with forced ventilation, i.e. with the ventilation equipment or with the air conditioning equipment.

Key words: indoor air temperature, humidity, air condition.

During the last time period there is needed a responsible and economical approach in the area of technical equipment of buildings, taking into consideration a reduced amount of natural raw stocks. There are required ecologically and economically conceptual solutions of systems and equipment in order to ensure a comfortable stay of people inside of buildings. One of the most important questions during construction of new buildings, as well as in the case of reconstruction of old buildings, is an efficiency of energy utilization. The newly projected buildings are insulated thermally; however a negative impact of this fact is reduction of a natural exchange of the air even below the hygienic minimum. The ventilation processes are relevant also with regard to the energetic efficiency of the buildings. Optimisation of ventilation intensity can be reached by means of forced ventilation instead of natural ventilation. It is necessary to ensure hygienically required amount of air predominately and the following step is determination of energetic requirement of ventilation.

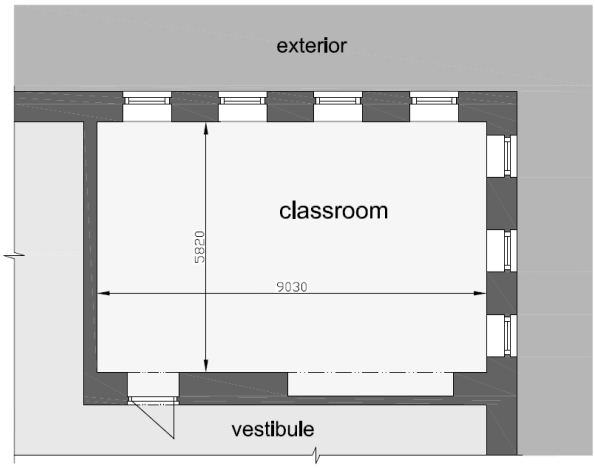

Fig. 1. Ground-plan of the analysed classroom

If the ventilation is reduced significantly, in this way can be reached a saving of energy, which is required for heating, but the indoor air will be depreciated together with a possible occurrence of negative impacts to people in the room. Other negative consequences are fungi and danger of illnesses. Taking into consideration the expensive investment costs and operational costs of air conditioning equipment, so a proposed solution could be the opening of windows according to the actual requirements. However, persons during the working process are not able to perceive the gradually increasing concentration of the CO_2 because of working attention and adaptation of nose receptors.

Fig. 2. The analysed classroom

The main purpose of this research is investigation of influence of the indoor air temperature, humidity and CO_2 concentration on a human behaviour in the two different areas: in the area with natural ventilation, i.e. without ventilation equipment and in the second area with forced ventilation, i.e. with the ventilation equipment or with the air conditioning equipment. The next task is to specify buildings intended for an unavoidable installation of ventilation unit equipped also with a recuperation system.

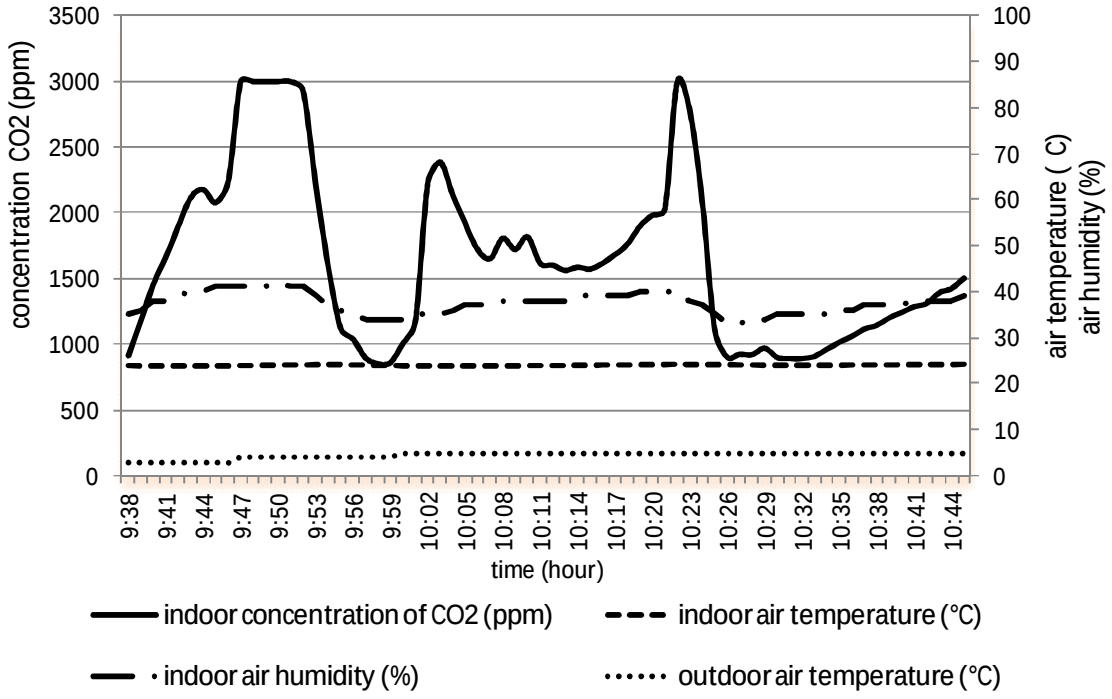

Fig. 3. Time behaviour of indoor temperatures, humidity and CO2 concentration

One of the methods, how to reach the above-mentioned purposes, is development of a multi-criteria method for ventilation efficiency evaluation. There is described in the next chapter the method of multi-criteria evaluation, which is developed for a classroom, taking into consideration the CO_2 loading. In the same way it will be possible to perform the evaluation also for the indoor temperature, speed of indoor air streaming, as well as for subjective perceiving of respondents. The final result should be a proposal of the multi-criteria evaluation from the energetic point of view.

Multi-Criteria Methodology for Evaluation of Classroom Ventilation Efficiency. The basic principle of the proposed analysis consists in finding of a "CO_2-key" for the given room, which is ventilated with an insufficient efficiency. It is necessary to define an optimal order of classrooms planned for the future installation of the controlled air conditioning, taking into consideration a reduce amount of finances, what is a situation typical for the educational institutions. There is analysed in this article just such classroom, which is loaded by the CO_2 in a most, because of the insufficient ventilation possibilities and therefore just in this room should be air-condition installed preferentially.

The second step is creation of the criteria groups according to their importance. The distribution should be as follows, for example:

Personal group of criteria (e.g. number of persons, weight of persons, age, etc.)

- health group of criteria (e.g. problems with respiration, fatigue, discomfort, etc.);
- environmental group of criteria (e.g. other loadings in the room, intensity of source consumptions, sustainability, etc.);
- group of activities (e.g. physical and psychical activities – standing, sitting, walking, etc.);
- energetic group of criteria (e.g. production of heat, creation of the CO_2, consumption of electric energy, etc.);
- building group of criteria (e.g. dimensions, arrangement, number and type of windows, suitability of air-condition installation, etc.);
- financial group of criteria (investment and operational costs).

Selection of Relevant Criteria for Choose and Determination of their Polarity. The third step is selecting of the substantive criteria with an impact to selection of the analysed classroom and elimination of other irrelevant criteria. Dedicated units characterize every criterion individually. During the selecting process is important firstly a fact whether the given criterion fulfils conditions of separability, i.e. if the given criterion is important for evaluation or if it can be eliminated fully from the evaluation process. For example, in the case of the environmental group of criteria is important the indoor air humidity, but the number of the (closed) windows in the classroom is irrelevant. So, the criterion "number of closed windows" is excluded from the environmental framework.

In the next step is dedicated a polarity to the given criterion. If there is dedicated a sign "+", it means that the given criterion has a positive impact, i.e. it has an increasing influence during the ventilation efficiency analysis in the classroom. For example, an increasing number of students in the classroom requires a repeating ventilation, taking into consideration a necessity of the indoor air exchange and due this fact the number of students (like a concrete criterion) has an increasing influence or character. The negative polarity of the given criterion has a reducing influence during the evaluation, i.e. it is a smoothing factor. There is presented the table for input of values in the case of five chosen classrooms and seven criteria in the Table 1.

Data Collection and Evaluation Concerning Classrooms. During the fifth phase of the solution starts a collection and evaluation of data obtained by means of parameters of classrooms after the correct polarisation. There is chosen the smallest value of the given criterion from all the obtained and polarised criteria. Further the average value of this criterion is calculated for all classrooms. The individual evaluation of all given criterion is finished with calculation of the standard deviation.

The sixth step begins with a comparison of the chosen criteria and each of the values is compared with every other value mutually. So, there is compared the first criterion with the second, third and fourth criterion in the case of four defined criteria. Further it is compared the second criterion with the third and fourth criterion and finally, the third criterion with the fourth. Such methodology is applied for each of classrooms with intention of classroom reconstructions. The result of mutual comparison of values is a set of correlation coefficients obtained for every comparison. The correlation coefficients are from the interval (-1, 1).

Table 1

Table for composition of the multi-criteria evaluation of 5 classrooms with 7 criteria

		individual criteria of ventilation efficiency							optimal order for controlled air-condition installation
		1.	2.	3.	4.	5.	6.	7.	
		number of persons in room	outdoor air average temperature	indoor air average temperature	average concentration of CO_2	air streaming velocity	opened window area	ventilation time	
units:		[person]	[°C]	[°C]	[ppm]	[m/s]	[m^2]	[min]	
polarisation influence [+/-]:		-	+	-	-	+	+	+	
		values of criteria for individual classrooms							
classrooms	1	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}	a_{17}	Q_1
	2	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}	a_{26}	a_{27}	Q_2
	3	a_{31}	a_{32}	a_{33}	a_{34}	a_{35}	a_{36}	a_{37}	Q_3
	4	a_{41}	a_{42}	a_{43}	a_{44}	a_{45}	a_{46}	a_{47}	Q_4
	5	a_{51}	a_{52}	a_{53}	a_{54}	a_{55}	a_{56}	a_{57}	Q_5
minimum criterion value		n_1	n_2	n_3	n_4	n_5	n_6	n_7	
arithmetic average of criterion		$\bar{a}_1$	$\bar{a}_2$	$\bar{a}_3$	$\bar{a}_4$	$\bar{a}_5$	$\bar{a}_6$	$\bar{a}_7$	
standard deviation of criterion		s_1	s_2	s_3	s_4	s_5	s_6	s_7	
correlation coefficient		$r_{11}=0$	$r_{21}=r_{12}$	$r_{31}=r_{13}$	$r_{41}=r_{14}$	$r_{51}=r_{15}$	$r_{61}=r_{16}$	$r_{71}=r_{17}$	
		r_{12}	$r_{22}=0$	$r_{32}=r_{23}$	$r_{42}=r_{24}$	$r_{52}=r_{25}$	$r_{62}=r_{26}$	$r_{72}=r_{27}$	
		r_{13}	r_{23}	$r_{33}=0$	$r_{43}=r_{34}$	$r_{53}=r_{35}$	$r_{63}=r_{35}$	$r_{73}=r_{37}$	
		r_{14}	r_{24}	r_{34}	$r_{44}=0$	$r_{54}=r_{45}$	$r_{64}=r_{45}$	$r_{74}=r_{47}$	
		r_{15}	r_{25}	r_{35}	r_{45}	$r_{55}=0$	$r_{65}=r_{55}$	$r_{75}=r_{57}$	
		r_{16}	r_{26}	r_{36}	r_{46}	r_{56}	$r_{66}=0$	$r_{76}=r_{67}$	
		r_{17}	r_{27}	r_{37}	r_{47}	r_{57}	r_{67}	$r_{77}=0$	
reduction constant		k_1	k_2	k_3	k_4	k_5	k_6	k_7	

The seventh part of the analysis consists of a calculation of the reduction constants. The reduction constants enable to determine more precisely influence of the individual criteria on the ventilation efficiency coefficients. Values of these reduction constants are from the interval (0, 1) and for the every criterion is calculated the individual value of reduction.

The last step is calculation of the ventilation coefficients. There are applied the concrete numerical data of the minimum values, arithmetic means, standard deviations and reduction constants of the individual criteria.

Calculation of Ventilation Efficiency for Individual Classrooms. The multi-criteria analysis is finished by the determination of classroom with the minimum ventilation efficiency, i.e., such classroom, which has the coefficient with the minimal value. This room has the highest priority for installation of the controlled ventilation and air-condition. The classroom with the second lowest coefficient is the second room “in the list” or it is like a substitutive room for possible installation. The global sequence is demonstrated in the Fig. 4.

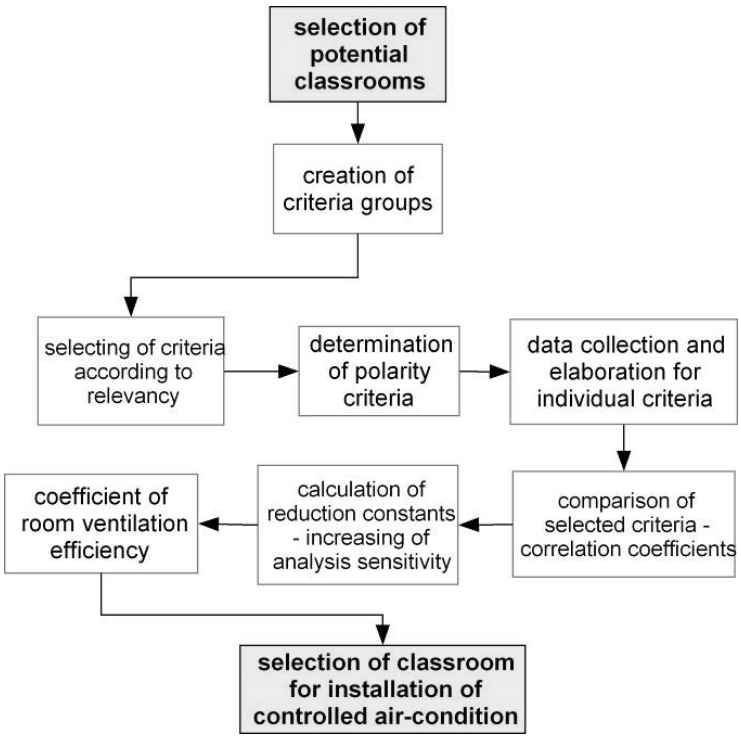

Fig. 4. Sequence diagram of multi-criteria analysis of ventilation efficiency

Conclusion. The multi-criteria methodology of selection serves as an auxiliary tool for making a decision where should be installed the controlled ventilation and air-conditioning preferentially.

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