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INDOOR ENVIRONMENT, AIR QUALITY, VENTILATION RATES – NUMERICAL CFD SIMULATIONS, CALCULATIONS AND MEASURING APPARATUS APPLICATION

ŚRODOWISKO WNĘTRZ, JAKOŚĆ POWIETRZA, WSKAŹNIKI WENTYLACJI – SYMULACJE NUMERYCZNE CFD, OBLICZENIA ORAZ ZASTOSOWANIE PRZYRZĄDÓW POMIAROWYCH

Abstract

The paper deal with quality in selected ventilated classroom. The basic assumption for a healthy indoor environment and optimum occupant performance is adequate fresh air amount without the physical and chemical pollutants. The physical and chemical pollutants in indoor environment are also produced by occupants. The carbon dioxide (CO_2) as chemical pollutant is produced by occupants respecting human activities. The carbon dioxide production is 4 percents of the total air exhaled amount at the temperature of 34°C to 36°C.

Keywords: CFD simulations, mixing ventilation, displacement ventilation, confluent ventilation, personal ventilation, air distribution index, carbon dioxide

Streszczenie

Niniejszy artykuł dotyczy jakości powietrza w wybranej wentylowanej sali lekcyjnej. Podstawowym założeniem zdrowego środowiska wnętrz oraz optymalnej wydajności użytkowania jest odpowiednia ilość świeżego powietrza z wykluczeniem wszelkich substancji zanieczyszczających pochodzenia fizycznego i chemicznego. Substancje tego typu wytwarzają też użytkownicy środowiska danego wnętrza. Dwutlenek węgla (CO2) jako substancja zanieczyszczająca pochodzenia chemicznego wytwarzany jest przez organizmy ludzkie. Wytwarzany dwutlenek węgla stanowi cztery procent całkowitej ilości wydychanego powietrza w temperaturze od 34°C do 36°C.

Słowa kluczowe: symulacje CFD, wentylacja mieszana, wentylacja przesunięcia, wentylacja zbieżna, wentylacja osobista, wskaźnik dystrybucji powietrza, dwutlenek węgla

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1. Introduction

Several types of air distribution schemes (17 schemes) were selected for presented experiment within the frame of mechanical ventilation systems (mixing, personal, confluent and displacement) and existing natural ventilation system (infiltration by windows).

The distribution systems were installed in naturally ventilated school building in identical classrooms. The carbon dioxide (CO_2) concentrations were studied under indoor climate parameters (temperature, relative humidity and air movement). Three different categories for evaluating of indoor environment are specified for indoor ventilated spaces. Category I corresponds to a high level of expectation and is recommended for spaces occupied by very sensitive and fragile persons with special requirements like handicapped, sick, very young children and elderly persons. Category II corresponds to normal level of expectation and should be used for new buildings and renovations. Category III corresponds to an acceptable, moderate level of expectation and may be used for existing buildings. Values outside the criteria for the above the categories should only be accepted for a limited part of the year.

Recommended values of indoor CO_2 concentration for ventilated buildings are estimated as concentration above outdoor concentration. Recommended CO_2 concentration is 350ppm for category I, 500ppm for category II, 800ppm for category III and over the 800ppm for category IV above background outdoor concentration for energy calculations and demand control [1, 2, 3].

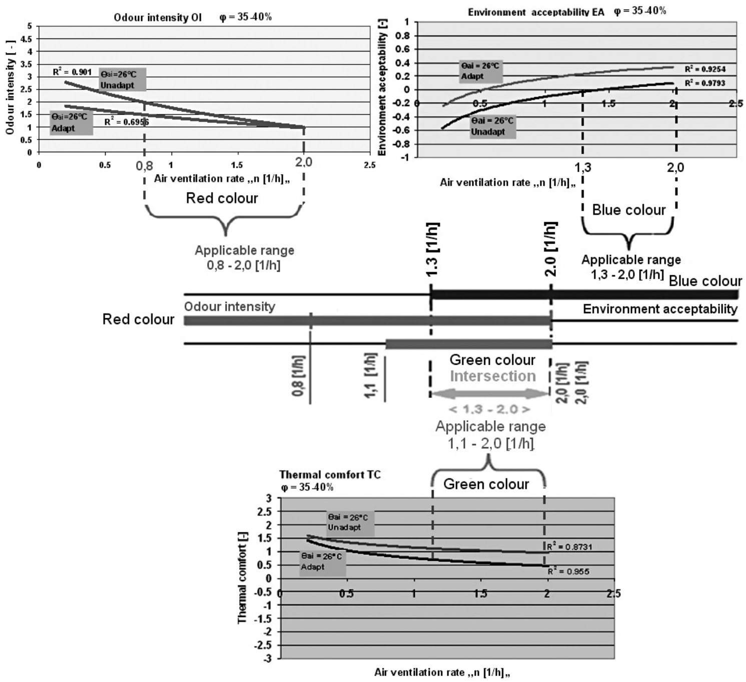


Fig. 1. Total ventilation rates – determination of applicable range (θai = 26°C, φ = 35-45%)

Rys. 1. Narzędzia pomiaru parametrów obiektywnych

1.1. Total air ventilation rate determination – tested air flow value

Total air ventilation rates were determined from results on the basis of sensory analysis of odour intensity, environment acceptability, thermal comfort evaluation and experimental measurements (Fig. 1).

The evaluation of total air ventilation rate in related to odour intensity, environment acceptability and thermal comfort is presented in Fig. 1. The applicable range of values of air ventilation rate, where odour intensity (OI) presents executed criterion "OI < 2" are presented by red colour in the range of 0,8 to 2,0[1/h]. The applicable values of air ventilation rate, where environment acceptability (EA) presents executed criterion "EA > 0" are presented by blue colour in the range 1,3 to 2,0 [1/h]. The applicable values of air ventilation rate, where thermal comfort (TC) presents executed criterion "<0; 1>" are presented by green colour in the range 1,1 to 2,0 [1/h].

The total air ventilation rate by mechanical ventilation in the range (<1,3; 2,0>) by mathematics intersection of 3 sets of numbers [(<0,8;2.0>)Λ(<1,3;2.0>)Λ(<1,1;2.0>)] was estimated.

The first idea was application the lowest possible air ventilation rate like value input for next real experimental measurements and also like value input to CFD simulations. Based on this assumption the air ventilation rate was established to value n_{TOT}=1,3 [1/h].

Partial conclusion

The air ventilation rates defined in Standard STN EN 15 251:2007 [1,2,3] present air change rate in which the objective benefit of proper selection of ventilation system and air distribution scheme is lost (erased) in relation to IAQ. The total ventilation rate "n_{TOT}" was determinated by sensory evaluation application. It was reason how to determine major boundary condition (air quantity = air ventilation rate) for minimizing of responsibility size of air quantity (quantitative component of ventilation) and maximize the impact of the choice of distribution scheme and the distribution element (qualitative component of ventilation) for transfer and distribution of pollutants in research.

The total air ventilation rate for next experimental measurements was established as the intersection of three air ventilation rates according to research harmonogram. This air ventilation rate was necessary to supply to occupant to experimental classroom and also as input value to CFD simulations.

The total air ventilation rate n_{TOT}= 1,3 [1/h] presents air ventilation rate taking into account the impact of air infiltration n_{INF}= 0,3 [1/h].

The perceived quality and sensory evaluation are considered acceptable for air ventilation rates which ensure that the requirements above will be executed. In the light of these facts holds:

– odour intensity was less than 2 (OI<2) at air ventilation rates in range of 0,8 to 2,0[1/h];
– environmental acceptability was bigger than 0 (EA>0) at air ventilation rates in range of 1,3 to 2,0 [1/h] ;
– thermal comfort is suitable from 0 to 1 (TC (<0; 1>)) at air ventilation rates in range of 1,1 to 2,0 [1/h].

The measurements were realized only to air ventilation rate n= 2,0 [1/h] for determination of minimize required air ventilation rate. From the results is evident that these criterias are executed at higher air ventilation rate than $n=2{,}0$ [1/h]. The results are presented in Fig. 1. This assumption is-but irrelevant for measurement purposes of this research.

The total minimum air ventilation rate is determined by $n_{TOT}=1{,}3$ [1/h]. In that $n_{TOT}=n_{INF}+n_{MECH}$ and then $q_{TOT}=q_{INF}+q_{MECH}$, the total air ventilation rate is $q_{TOT}=69.3$ [litre/s] or (250 m^3/hr).

1.2. Methods and conditions

Presented REM and CFD simulations mention to performance and ventilation efficiency. Ventilation systems are presented by 17 air distribution schemes (1 natural, 10 distribution schemes of mixing ventilation, 1 distribution scheme of confluent ventilation, 4 distribution schemes of displacement ventilation and 1 distribution scheme of personal ventilation).

Distribution schemes are devided to 3 corpuses (for CFD simulations). Corpus A present total ventilation rate 16 l/s (natural ventilation, infiltration – distribution scheme 1), corpus B present total ventilation rate 69,3 l/s (distribution schemes 2, 3A, 4A, 5, 6, 7, 8, 9, 10, 11, 12, 13A, 14A, 15A, 16A and 17A) and corpus C present total ventilation rate 108,8 l/s (distribution schemes 3B, 4B, 13B, 14B, 15B, 16B and 17B).

The REM was realized only for distribution schemes 1, 2, 3A, 4A, 4B and 5 (because difficult technical conditions for measurements).

The results from CFD and REM were compared (1, 2, 3A, 4A, 4B and 5) and deviation for others CFD without REM (2, 3AB, 4AB, 5, 6, 7, 8, 9, 10, 11, 12, 13AB, 14AB, 15AB, 16AB and 17AB) was determined.

The 21 measuring points were located in occupied zone and 3 points out of this one for REM. As experimental model room for study investigations the university classroom was used. The model room is especially used for these measuring purposes. The floor area of model is 62 m^2 and the ceiling height is 3,1 m. Occupancy simulators and furniture arrangements were designed to fit the field measurement conditions (Fig. 2).

To produce the heat-load corresponding to fully occupied classroom, heat source-simulators were placed in the room. Also carbon dioxide concentrations was simulated by 21 CO_2 person-simulators which were placed in the room in breathing zone of sitting person (1,05 m above the floor).

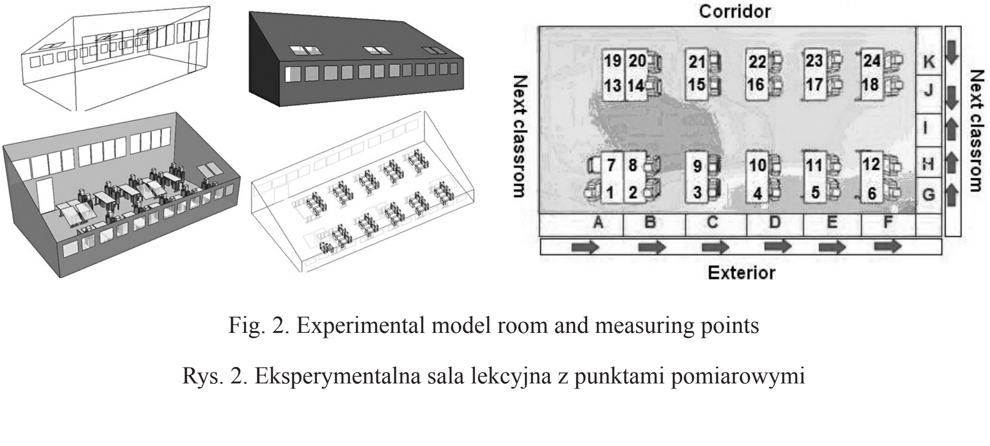


Fig. 2. Experimental model room and measuring points

Rys. 2. Eksperymentalna sala lekcyjna z punktami pomiarowymi

All measurements were carried out under steady state conditions. The steady state conditions are conditions that are permanently maintained by HVAC systems. The values of steady state conditions are presented describe in Table 1. The indoor air temperature was kept on level 20°C ± 2°C.

Table 1

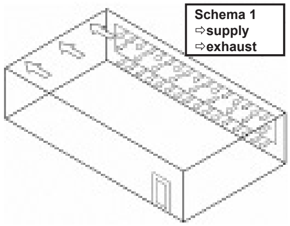
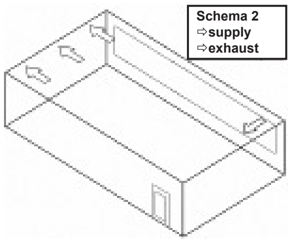
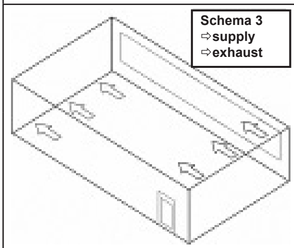
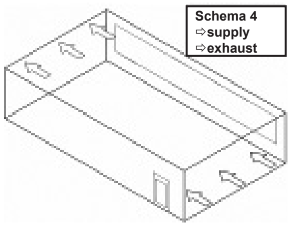
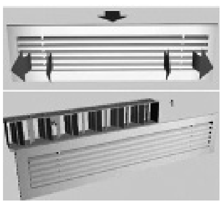
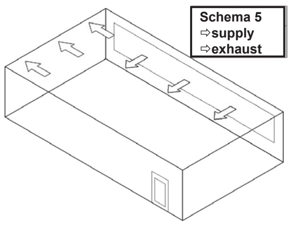
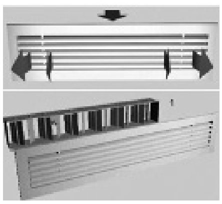
Characteristics of steady state conditions

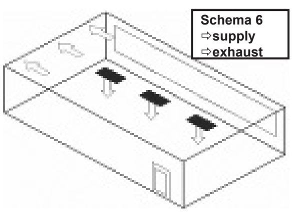
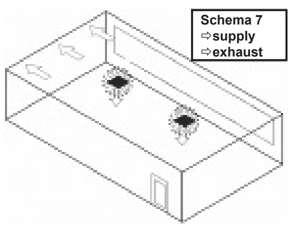
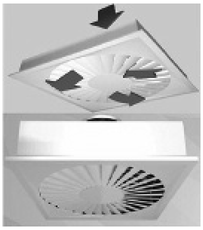
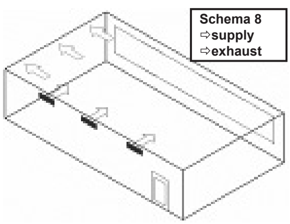
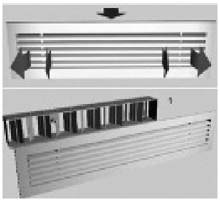
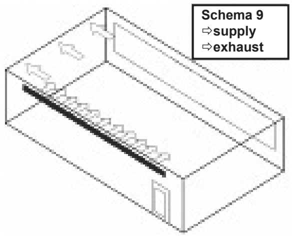
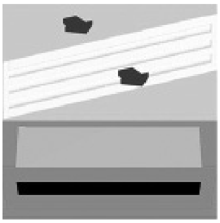
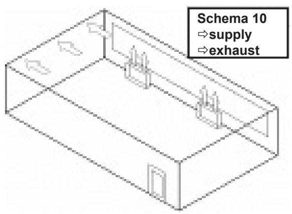
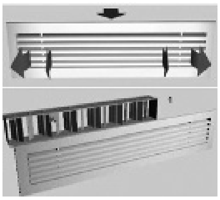
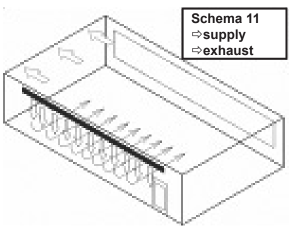
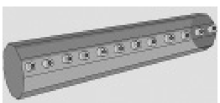
Ventilation system	Total ventilation rate q_{TOT} [l/s]	Number of distributions	Average surface temperature [°C]	Average supply air temperature [°C]		Average supply air humidity [%]	Average CO_2 concentration [ppm]		Air velocity [m/s]
				Θas	θoa	φas	Co	Ci	
Natural ventilation	16	1	18,5	22,0 ± 2°C	15,5	50	360-400	378	<0,15
Mechanical ventilation A (CFD+REM)	69,3	16	18,5	22,0 ± 2°C	15,5	50	360-400	378	<0,25
Mechanical ventilation B (CFD)	108,8	7	18,5	22,0 ± 2°C	15,5	50	360-400	378	<0,25

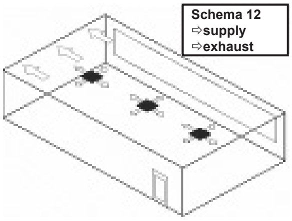
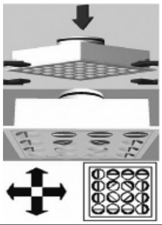
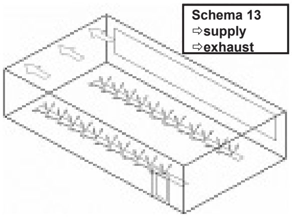
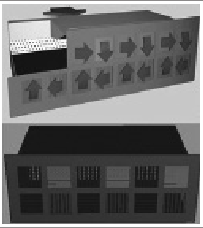
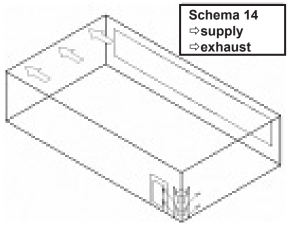
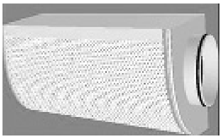
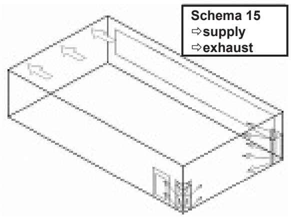
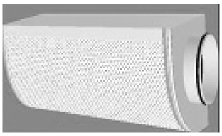
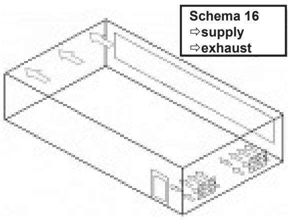
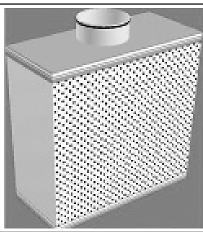
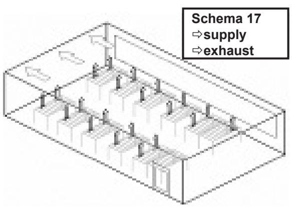
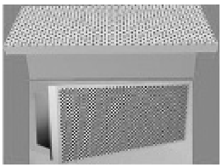
Individual distribution schemes in Table 2 present illustration sketch of distribution scheme, figure of distribution element, the methods of research and detailed ventilation characterization. The ventilation is characterized by position of air supply input and air exhaust output but also by ventilation rates.

Table 2

Distribution schemes – characterization and describe

Distribution scheme	Distribution element	Method	Ventilation characterization	
	Infiltration by windows 	REM CFD-IESVE	1	Natural ventilation q_{TOT} = 16 [l/s]
	1 input by circle duct 	REM CFD-IESVE	2	Mixing ventilation, supply by 1 inlet in duct, q_{TOT} = 69,3 [l/s]
		REM CFD-IESVE	3A	Mixing ventilation, supply by 3 inlets in duct under ceiling, angle lamella -45°, q_{TOT} = 69,3 [l/s]
			3B	Mixing ventilation, supply by 3 inlets in duct under ceiling, angle lamella -45°, q_{TOT} = 108,8 [l/s], category III (STN EN 15 251)
		REM CFD-IESVE	4A	Mixing ventilation, supply by 3 inlets in duct above floor, angle lamella +45°, q_{TOT} = 69,3 [l/s]
			4B	Mixing ventilation, supply by 3 inlets in duct above floor, angle lamella +45°, q_{TOT} = 108,8 [l/s], category III (STN EN 15 251)
		REM CFD-IESVE	5	Mixing ventilation, horizontal convection, 3 inlets under windows, q_{TOT} = 69,3 [l/s]

		CFD-IESVE	6	Mixing ventilation, vertical convection, 3 inlets under ceiling, q_{TOT} = 69,3 [l/s]
		CFD-IESVE	7	Mixing ventilation, vertical convection, 2 whirling inlets under ceiling, q_{TOT} = 69,3 [l/s]
		CFD-IESVE	8	Mixing ventilation, horizontal convection under ceiling, angle lamella 0°, 3 inputs on side wall, q_{TOT} = 69,3 [l/s]
		CFD-IESVE	9	Mixing ventilation, horizontal convection under ceiling, angle lamella 0°, 1 input on side wall, q_{TOT} = 69,3 [l/s]
		CFD-IESVE	10	Mixing ventilation, air convection to windows, 2 fancoil unit inputs under windows, q_{TOT} = 69,3 [l/s]
		CFD-IESVE	11	Confluent ventilation, air convection with angle -30° to wall, 1 confluent input on wall above students, q_{TOT} = 69,3 [l/s]

		CFD-IESVE	12	Mixing ventilation, vertical air convection, 3 multi-diffusor inputs (perforated) under ceiling, q_{TOT}= 69,3 [l/s]
		CFD-IESVE	13A	Displacement ventilation, vertical air convection from floor, 2 line floor diffuser inputs, q_{TOT}= 69,3 [l/s]
			13B	Displacement ventilation, vertical air convection from floor, 2 line floor diffuser inputs, q_{TOT}= 108,8 [l/s], category III (STN EN 15 251)
		CFD-IESVE	14A	Displacement ventilation, 1 corner diffuser input in wall, q_{TOT}= 69,3 [l/s]
			14B	Displacement ventilation, 1 corner diffuser input in wall, q_{TOT}= 108,8 [l/s], category III (STN EN 15 251)
		CFD-IESVE	15A	Displacement ventilation, 2 corner diffuser inputs in wall, q_{TOT}= 69,3 [l/s]
			15B	Displacement ventilation, 2 corner diffuser inputs in wall, q_{TOT}= 108,8 [l/s], category III (STN EN 15 251)
		CFD-IESVE	16A	Displacement ventilation, 2 straight diffuser inputs in wall, q_{TOT}= 69,3 [l/s]
			16B	Displacement ventilation, 2 straight diffuser inputs in wall, q_{TOT}= 108,8 [l/s], category III (STN EN 15 251)
		CFD-IESVE	17A	Personal ventilation, vertical air convection, 21 perforated inputs integrated in desk, q_{TOT}= 69,3 [l/s]
			17B	Personal ventilation, vertical air convection, 21 perforated inputs integrated in desk, q_{TOT}= 108,8 [l/s], category III (STN EN 15 251)
REM – real experimental measurements				
IESVE – dynamic simulation software CFD				

1.3. The air distribution indices – Air distribution index

The air distribution index (ADI) presented by Awbi used for ventilation systems comparison was used for study of designed distribution systems from IAQ point of view [4]. To assess the effectiveness of ventilation system in measurements, the effectiveness for heat removal (ε_T) and contaminant removal (ε_C) are used together with predicted percentage of dissatisfied (PPD) for thermal comfort and percentage of dissatisfied (PD) for air quality [5]. The heat removal effectiveness (ε_T) and contaminant removal effectiveness (ε_C) are defined (1, 2). The effectiveness ranges for ε_C is evident from Table 3.

Table 3

The ε_C value range

Effectiveness ε_C	Consequence
$0 < \varepsilon_C < 1.0$	Cumulation
$\varepsilon_C = 1.0$	Total mixing
$1.0 < \varepsilon_C < \infty$	Dilution

$$\varepsilon_C = \frac{C_E - C_S}{C_m - C_S} \ [-] \tag{1}$$

$$\varepsilon_\theta = \frac{\Theta_E - \Theta_S}{\Theta_m - \Theta_S} \ [-] \tag{2}$$

where:
θ_E – air exhaust temperature,
θ_S – air supply temperature,
θ_m – mean air temperature in occupancy zone,
C_E – air exhaust concentration,
C_S – air supply concentration,
C_m – mean air concentration in occupancy zone.
PD and *PPD* values represent predicted percentage of large panel dissatisfied with thermal comfort and it is defined as a function of predicted mean vote (PMV) (3, 4). Air distribution index is influenced by comfort number (N_T) and air quality number (N_C) (3–7) [6–10].
where:

$$PPD = 100 - 95.e^{-\left(0{,}03353.PMV^4 + 0{,}2179.PMV^2\right)} \ [\%] \tag{3}$$

$$PD = 35.e^{-1{,}83.q_{TOT}^{0{,}25}} \ [\%] \tag{4}$$

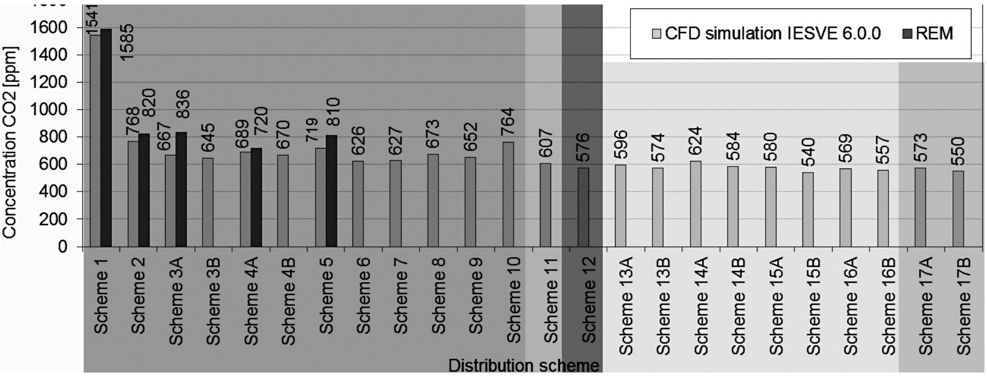
q_{tot} – total ventilate rate per source [l/s.source]

$$N_T = \frac{\varepsilon_T}{PPD} \qquad N_C = \frac{\varepsilon_C}{PD} \qquad ADI = \sqrt{\left(N_T \cdot N_C\right)} \ [-] \tag{5, 6, 7}$$

2. Results and discussion

This paper shows some promising ways to go for that goal and the successful optimization of ventilation design using simulations. The paper compared air distribution schemes with aim to find out the most suitable distribution of ventilation systems for studied experimental model room. The best ventilation strategy in relation to CO_2 concentration value seems to be displacement distribution schemes and personal ventilation schemes. Expectations from confluent ventilation (Scheme 11) respecting CO_2 concentration were repleted.

The field measurements in-situ (tracer gas technique by CO_2) and CFD simulations in IESVE 6.0.0 for 5 different ventilation systems confirmed that the indoor air quality in the schools is generally unacceptable (out of category I, II and III) by lower ventilation rates for NV because of not respecting the occupancy density. Some distribution schemes of MV, DV and PV represent category I, II – acceptable.



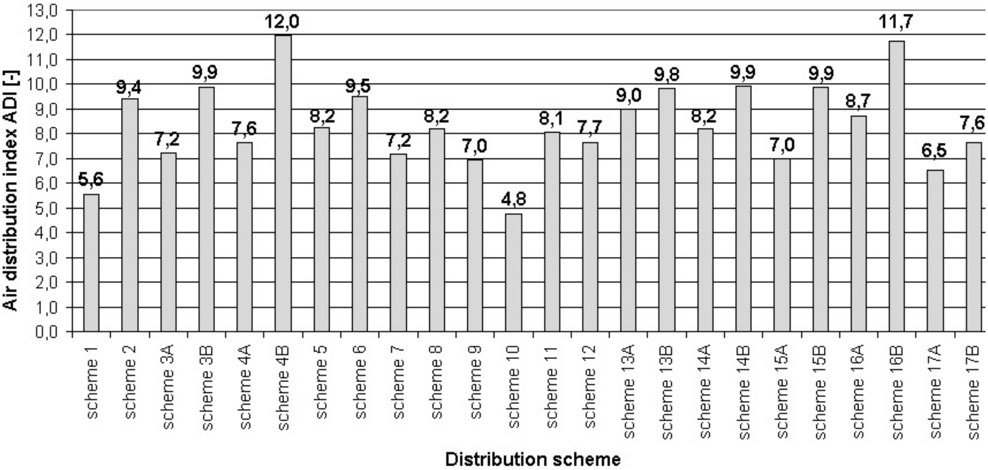
Scheme number	Ventilation system type	q_{TOT} [l/s]	Scheme number	Ventilation system type	q_{TOT} [l/s]	Scheme number	Ventilation system type	q_{TOT} [l/s]
Scheme 1	Natural ventilation	16	Scheme 7	Mixing ventilation	69.3	Scheme 14A	Displacement ventilation	69.3
Scheme 2	Mixing ventilation	69.3	Scheme 8	Mixing ventilation	69.3	Scheme 14B	Displacement ventilation	108.8
Scheme 3A	Mixing ventilation	69.3	Scheme 9	Mixing ventilation	69.3	Scheme 15A	Displacement ventilation	69.3
Scheme 3B	Mixing ventilation	108.8	Scheme 10	Mixing ventilation	69.3	Scheme 15B	Displacement ventilation	108.8
Scheme 4A	Mixing ventilation	69.3	Scheme 11	Confluent ventilation	69.3	Scheme 16A	Displacement ventilation	69,3
Scheme 4B	Mixing ventilation	108.8	Scheme 12	Mixing ventilation	69.3	Scheme 16B	Displacement ventilation	108.8
Scheme 5	Mixing ventilation	69.3	Scheme 13A	Displacement ventilation	69.3	Scheme 17A	Personal ventilation	69.3
Scheme 6	Mixing ventilation	69.3	Scheme 13B	Displacement ventilation	108.8	Scheme 17B	Personal ventilation	108.8

Fig. 3. Total carbon dioxide (CO_2) concentrations for individual distribution schemes (time 3600 s, CFD simulation IESVE 6.0.0 and REM) - Results of objective parameters

Rys. 3. Stężenia dwutlenku węgla (CO2) dla poszczególnych układów dystrybucyjnych (czas 3600 s, symulacja CFD IESVE 6.0.0 i REM) – wyniki parametrów obiektywnych

The simulations results showed that the main problem is also space geometry characterization not only distribution systems. The simulation Scheme 1 is presented as the worst distribution scheme respecting IAQ and Scheme 15B, 17B as the best distribution scheme respecting IAQ. The results are presented on Fig. 3.

The values of air distribution index (ADI) are presented on Fig. 4. The index ADI connects both subjective and objective parameters (thermal comfort, carbon dioxide concentration, comfort number, PPD, PMV, air velocity) of indoor air quality. Expectations from confluent ventilation (Scheme 11) respecting CO_2 concentration and subjective parameters were repleted.



Scheme number	Ventilation system type	q_{TOT} [l/s]	Scheme number	Ventilation system type	q_{TOT} [l/s]	Scheme number	Ventilation system type	q_{TOT} [l/s]
Scheme 1	Natural ventilation	16	Scheme 7	Mixing ventilation	69.3	Scheme 14A	Displacement ventilation	69.3
Scheme 2	Mixing ventilation	69.3	Scheme 8	Mixing ventilation	69.3	Scheme 14B	Displacement ventilation	108.8
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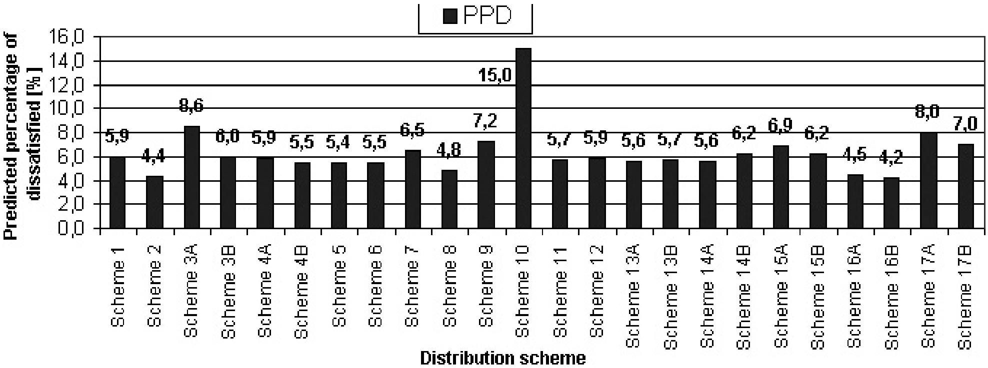
Scheme 4A	Mixing ventilation	69.3	Scheme 11	Confluent ventilation	69.3	Scheme 16A	Displacement ventilation	69,3
Scheme 4B	Mixing ventilation	108.8	Scheme 12	Mixing ventilation	69.3	Scheme 16B	Displacement ventilation	108.8
Scheme 5	Mixing ventilation	69.3	Scheme 13A	Displacement ventilation	69.3	Scheme 17A	Personal ventilation	69.3
Scheme 6	Mixing ventilation	69.3	Scheme 13B	Displacement ventilation	108.8	Scheme 17B	Personal ventilation	108.8

Fig. 4. Air distribution index values for individual distribution schemes (time 3600 s, CFD simulation IESVE 6.0.0 and REM).Results of combination of subjective and objective parameters

Rys. 4. Wartości wskaźnika dystrybucji powietrza dla poszczególnych układów dystrybucyjnych (czas 3600 s, symulacja CFD IESVE 6.0.0 i REM) – wyniki łączonych parametrów subiektywnych i obiektywnych

The values of predicted percentage of dissatisfied (PPD) are presented in Fig. 5. The lowest air distribution index achieved for the mixing ventilation system and the distribution scheme 10 also confirmed the highest percentage of dissatisfied occupants is the most unhappy of all distribution systems. The second worst value reached a distribution diagram No. 3A (mixing ventilation). Also, the personnel assigned to the ventilation is increased dissatisfaction which is mainly due to higher speeds in the user's head. Speed has a significant impact on the subjective perception of well-being in indoor environments, which resulted in the person ventilation.

The values of comfort level are presented on Fig. 6. The highest comfort level was achieved by confluent ventilation (Scheme 11) and lowest by mixing ventilation (Fig. 10). Lower comfort level was experienced by personnel ventilation, again mainly due to higher flow air velocities toward the occupant.



Scheme number	Ventilation system type	q_{TOT} [l/s]	Scheme number	Ventilation system type	q_{TOT} [l/s]	Scheme number	Ventilation system type	q_{TOT} [l/s]
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Scheme 4B	Mixing ventilation	108.8	Scheme 12	Mixing ventilation	69.3	Scheme 16B	Displacement ventilation	108.8
Scheme 5	Mixing ventilation	69.3	Scheme 13A	Displacement ventilation	69.3	Scheme 17A	Personal ventilation	69.3
Scheme 6	Mixing ventilation	69.3	Scheme 13B	Displacement ventilation	108.8	Scheme 17B	Personal ventilation	108.8

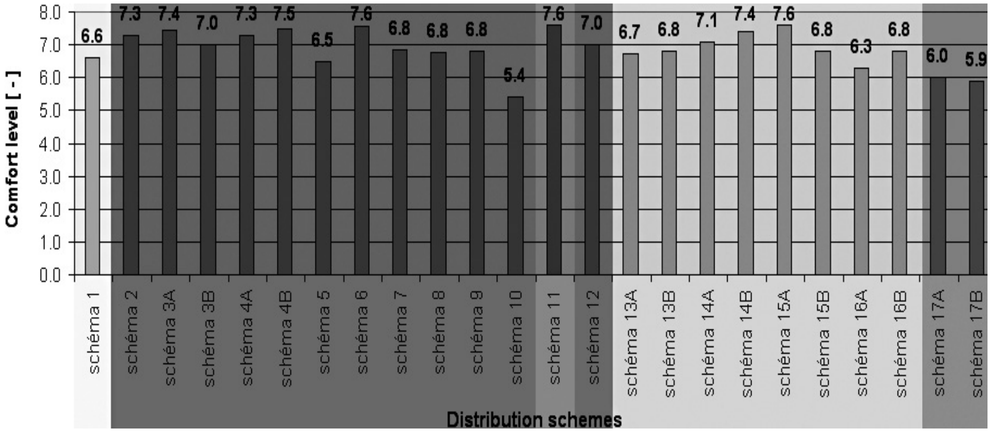
Fig. 5. PPD values for individual distribution schemes
(time 3600 s, CFD simulation IESVE 6.0.0 and REM) – Results of subjective parameters

Fig. 5. Wartości przewidywanego odsetka niezadowolonych użytkowników dla poszczególnych układów dystrybucyjnych (czas 3600 s, symulacja CFD IESVE 6.0.0 i REM) – wyniki parametrów subiektywnych

This paper shows some promising ways to go for that goal and the successful optimization of ventilation design using simulations. The paper compared air distribution schemes with aim to find out the most suitable distribution of ventilation systems for studied experimental model room.

The best ventilation strategy in relation to CO_2 concentration and subjective parameters seems to be displacement distribution schemes and personal ventilation schemes. Also mixing ventilation schemes (scheme 2 and 5, 6) show good results, but scheme 2 allocate discomfort in relation to air velocity.

Distribution schemes 3B, 4B, 13B, 14B, 15B and 16B show very good results but in relation to increased ventilation rate (corpus B).



Scheme number	Ventilation system type	q_{TOT} [l/s]	Scheme number	Ventilation system type	q_{TOT} [l/s]	Scheme number	Ventilation system type	q_{TOT} [l/s]
Scheme 1	Natural ventilation	16	Scheme 7	Mixing ventilation	69.3	Scheme 14A	Displacement ventilation	69.3
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Scheme 3A	Mixing ventilation	69.3	Scheme 9	Mixing ventilation	69.3	Scheme 15A	Displacement ventilation	69.3
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Scheme 5	Mixing ventilation	69.3	Scheme 13A	Displacement ventilation	69.3	Scheme 17A	Personal ventilation	69.3
Scheme 6	Mixing ventilation	69.3	Scheme 13B	Displacement ventilation	108.8	Scheme 17B	Personal ventilation	108.8

Fig. 6. The comfort level for distribution schemes (simulation output IESVE 6.0.0) – Results of subjective and objective parameters

Fig. 6. Poziom wygody dla układów dystrybucyjnych (wydajność symulacji IESVE 6.0.0) – wyniki parametrów subiektywnych i obiektywnych

The air distribution index (ADI) is used for global comparison of ventilation systems. Index ADI combines parameters such as PPD, PMV, ε_c, ε_Θ, P_D, that combines objective but also subjective assessment parameters. It is this index takes into account the accurate distribution scheme efficiency ventilation system taking into account the subjective parameters of users. The best results are reported for the scheme displacement ventilation with low flow A (Fig. 14A, 11) and an increased flow of B (13B, 14B, 15B and 16B). Similar indices slightly below the ADI experienced mixing ventilation systems and low flow (2, 6) and an increased flow of B (3B and 4B). Worse is the result of personal ventilation compounded by poor subjective (sensory) results. Although personal ventilation dispose by excellent results kCO_2 higher PPD and PMV values do not allow the ventilation system to excel. The biggest unexpected drop was reported by new air ventilation system – confluent ventilation. Under the generally very good results also have been signed the fact that the classroom was not overloaded by the number of students (in many real cases – not our research, low indoor air quality is caused also by inadequately high space occupancy). In our research the number of students was estimated according to valid Slovak (European) Standards.

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References

[1] STN EN 15251:2007 Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics.

[2] STN EN ISO 7730: 1994. Moderate thermal environments.Determination of the PMV and PPD indices and specification of the conditions for the thermal comfort PMV a PPD a špecifikácia podmienok na tepelnú pohodu.

[3] STN EN 13 779:2007 Ventilation in non-residential buildings. General requirements for ventilation and air conditioning equipments.

[4] Karimipanah T., Awbi H.B., Blomqvist C., Sandberg M., *Effectivness of confluent jets ventilation system for classroom*. Proc. Indoor Air 2005, 10th International Conference on Indoor Air Quality and Climate, Beijing, China, 2005, 3271-3277.

[5] Regard M., Carrie F.R., Voeltzel A., Richalet V., *Measurement and CFD modelling of IAQ indexes*. Proc. 16-th Air Infiltration and Ventilation Centre Conference, Implementing the Results of Ventilation Research, vol.1, USA, 287-294.

[6] Karaimpanah T., Sandberg M., Awbi H.B., *A comparative study of different air distribution systems in a classroom*, Proceeding of International Conference on Indoor Air Quality and Climate. Roomvent, 2000, 1013-1018.

[7] Karaimpanah T., Moshfegh B., *On the performance of confluent jets ventilation system in office space*, Proceeding of the 10th International Conference on Air distribution in rooms. Finland (CFD models and methods), Roomvent 2007.

[8] Zhou L., Wan M.P., Chao C.Y.H., Haghighat, F., *A comparison of an underfloor air system and mixing system: Measurement and CFD simulations*, *Creating a healthy indoor environment for people - Ventilation*, Healthy Buildings 2006, 299-304.

[9] Cho Y., Awbi H.B., Karimipanah T., *Comparison between wall confluent jets and displacement ventilation in aspect of the spreading ratio on the floor*, Proceeding of the 10th International Conference on Indoor Air Quality and Climate. Beijing, China, 2005, 3249-3254.

[10] Jurelionis A., *CFD predictions of air distribution in classrooms*, Creating a healthy indoor environment for people – CFD, Healthy Buildings 2006, 129-134.