Ventilation and air conditioning for school buildings

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Abstract. One of the basic problems of school buildings is the unsatisfactory thermal insulation properties of peripheral building structures. Unsatisfactory, especially in terms of the creation and long-term maintenance of microclimatic conditions in the classroom, is the complete absence of mechanical ventilation systems. In almost all schools, ventilation is based on the natural exchange of air through windows. Such a solution is no longer satisfactory today. In the old school buildings, the old ventilation shafts were usually abolished and in the new schools, there are no such shafts at all. In general, in many places, it is also forbidden to open windows during breaks for safety reasons. In addition, the method of window ventilation is based only on the subjective feelings of teachers and students; and since the human factor is unable to determine sufficient air quality with the help of its organs, the result is that the interior is not sufficiently ventilated. This also results in an unacceptable concentration of CO_2 in the classroom, a high level of resistance, an increasing level of relative humidity, and dust content in the indoor air. This is an unacceptable situation for teachers 'and students' health. The quality of the indoor environment of school buildings directly impacts the ability to concentrate and the attention of teachers and students. In this article, we will take a closer look at 6-week experimental measurements of the indoor microclimate in kindergarten. The measurement took place in two rooms, a playroom and a bedroom, where there were 22 children plus 1 or 2 adults at the same time. The measurement results for some quantities are acceptable, but in particular, the concentration of carbon dioxide is unacceptable.

Keywords. Ventilation, indoor microclimate, kindergarten, children, school, students.
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1. Introduction

Facilities for children and youth are established in a health-friendly environment, which is protected from harmful environmental factors, especially against noise and air pollution sources, and the environment is protected from negative educational influences [1]. As well as the building of schools should be a non-toxic environment, also the school building itself, to be a wholesome environment for pupils and students [2]. However, most school buildings were established in the last century. Some have been reconstructed, but the condition of the indoor microclimate is still unsatisfactory. The microclimate conditions in schools must be as good as possible for the proper functioning of the classroom. Natural ventilation through windows is a good habit, but it does not guarantee sufficient air exchange and is counterproductive for schools located in busy areas. It is also not a good solution in terms of energy savings and the risk of children's exposure to disease, due to low temperatures [3].

2. Requirements for internal microclimates in education buildings in legislation

Microclimate conditions for school buildings can be found in several Slovak legal regulations, which are binding. The most important is the subsequent documents.

2.1 decree of the Ministry of Health of the Slovak Republic no. 259/2008 Coll. the title

Decree of the Ministry of Health of the Slovak Republic no. 124/2017 Coll. amendment to decree no. 259/2008, which lays down details on the requirements for the indoor environment of buildings and the minimum requirements for lower standard flats and accommodation facilities. In the Decree of the Ministry of Health of the Slovak Republic no. 259/2008 Coll., the table defines exactly what parameters of microclimate for school buildings.

Tab. 1 - Parameters of microclimate for rooms with special requirements [4].

Space	t_0 (°C)	φ (%)	n (h^{-1})
Facilities for children and youth			
playrooms and bedrooms for children up to 6 years of age	at least 22	30 to 70	5
washrooms and toilets for children under 6 years of age	at least 24	30 to 70	8
classrooms, games rooms, living rooms	20 to 24	30 to 70	3 to 8
gyms	15	30 to 70	5
changing rooms at gyms	at least 20	30 to 70	5
washrooms and toilets at gyms	at least 24	30 to 70	8
other changing rooms, corridors, toilets	at least 15	30 to 70	5
Schools, pre-school facilities			
gyms	15 to 17	30 to 70	5
nursery and kindergarten bedrooms	18 to 20 [c)]	30 to 70	5
classrooms, games rooms, living rooms	20 to 24 [c)]	30 to 70	3 to 8
isolation room	22 to 24	30 to 70	5

c) In pre-school facilities, t_0 values are determined 0.5 m above the floor.

2.2 decree of the Ministry of Regional Development of the Slovak Republic no. 527/2007 Coll.

Which lays down details on requirements for facilities for children and youth. The abovementioned document, specifically in §6 Operation of facilities for children and youth, sets out the conditions for heating, air exchange and also defines the supply of drinking water.

Heating - paragraph 2: In the preschool facility and the establishment for the care of preschool children, the temperature in the playroom and bedroom was ensured to be at least 22 °C and in the washroom and toilet at least 24 °C, in the facilities for children and young people, in addition to the facilities for children and youth mentioned in the previous point, the temperature was ensured: Classrooms and other rooms in which pupils work for four hours or more, at least 20 °C, rooms intended for teaching physical education at least 15 °C, changing rooms set up in areas intended for teaching physical education at least 20 °C, changing rooms and other areas for storing pupils' outer clothing at least 15 °C, corridors and toilets at least 15 °C. Air exchange – paragraph 4: In classrooms 20 to 30 m^3/h per student, in areas intended for teaching physical education 30 m^3/h per student, in changing rooms and other areas intended for storing outer clothing 20 m^3/h in one place, in washrooms 30 m^3/h per washbasin, showers 150 m^3/h up to 200 m^3/h for one shower, toilets 50 m^3/h per cubicle and 25 m^3/h per urinal [5].

Non-binding but professionally recommended technical norms include: Energy performance of buildings - Ventilation for buildings - Part 1: In-door environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting, and acoustics - Module M1-6

Because the creation of an indoor environment with centrally conditioned air requires large air distribution systems and relatively high energy requirements, in the vast majority of cases it is customary to design the volume of air handling unit only on the so-called hygienic minimum, which means ensuring that the legislation provides sufficient fresh air for people [6].

In each of the above documents, you can find a mention of why, how, and when to ventilate. The mentioned technical standard STN EN 16798-1: 2019 defines how school premises should be ventilated (**Tab. 2**).

Tab. 2 - Examples of recommended operating temperature design values for the design of buildings and environmental engineering systems [7].

Type of building (space)	Category	Operating temperature (°C)	
		Minimum for heating (winter season) ~ 1.0 clo	Maximum for cooling (summer season) ~ 0.5 clo
Offices and rooms with similar activities (classrooms) sedentary activities 1.2 met	II	20.0	26.0

3. Experimental measurement

Measurement of selected parameters of the indoor environment lasting 42 days was performed in the kindergarten.

3.1 measurement target

The aim of the experimental measurement was:

Verify that the indoor air temperature, relative indoor air humidity and carbon dioxide (CO_2) concentration in the kindergarten premises meet the requirements set out in the relevant legal documents and technical standards.

Assess whether legal and standard requirements are met, otherwise determine the reasons for noncompliance.

3.2 methodology in terms of measured parameters of the internal environment

The most important of the measured parameters was the indoor air temperature. All used recorders were equipped with a sensor for measuring the temperature and relative humidity of the indoor air.

The criterion for the thermal environment in the cold period is the lower limit value of the operating temperature t_0 of the indoor air. The following applies to the calculation of the operating temperature:

$$t_0 \cong (t_a + t_{mr})/2 \quad (°C) \qquad (1)$$

where:
t_a is the air temperature (°C),
t_{mr} is the mean radiant temperature of the surrounding surfaces (°C).

If the temperature of the surfaces in the room is approximately the same as the temperature of the indoor air in the room, the operating temperature can be exchanged for the indoor air temperature during practical measurements.

3.3 methodology in terms of measuring instruments

Measurements of indoor air temperature, indoor air relative humidity, and CO_2 concentration were performed using Comet (U3430) recorders (**Fig. 1**).

Fig. 1 - Recorder Comet U3430.

Measuring range and measuring accuracy of sensors:

Temperature sensor: -20 to +60 °C, ±0.4 °C,
Humidity sensor: 0 to 100 % RH, ±1.8 % (at a temperature of 23 °C in the range of 0 to 90 % RH),
CO_2 sensor: 0 to 5000 ppm, ± (50 ppm + 3 % of measured value) at 25 °C.

3.4 methodology in terms of time and measurement conditions

The measurement of selected quantities took place in the period from 22.03.2021 to 03.05.2021, i.e. 42 full calendar days, including weekends. Values were recorded at minute intervals. Due to the ongoing pandemic situation, the premises could be used by fewer children than usual.

3.5 methodology in terms of sensor placement

The measuring points were selected based on an agreement with the principal of the kindergarten. At the same time, the purpose of the measurement was the even distribution of recorders and recording of measured quantities in different types of rooms (in the bedroom and game room).

Recorders intended for continuous measurement were placed mainly on tables and cabinets. One of the recorders was hung in the middle of the room. All were informed about the ongoing measurements and were asked to take extra care to avoid shifting or damage to the measuring recorders.

Fig. 2 – Location of recorders.

4. Analysis of measurement results

4.1 requirements for indoor microclimate

The measurement was focused on the assessment of the microclimate as well as the quality of indoor air in selected rooms. The most significant factors that affect the microclimate are the temperature and relative humidity of the indoor air. In air quality, the decisive measured quantity was the concentration of carbon dioxide CO_2.

Tab. 3 - Optimal conditions of indoor microclimate and air quality.

Season of the year	Temperature of indoor air t (°C)			Permissible air velocity v (m/s)	Permissible relative humidity φ (%)	Carbon dioxide concentration (ppm)
	optimal	permissible				
		min.	max.			
warm V to IX	23 to 27	20	28	≤ 0.25	30 to 70	350 to 1500
cold IX to V	20 to 24	18	26	≤ 0.20	30 to 70	350 to 1500

4.2 measurement results

The results of measurements in the game room are shown in the graphs in the following figures. The thermal state in the game room at the individual measuring points by the requirements defined in legal and technical regulations was acceptable, as the indoor air temperature during the entire measurement period in the cold period was 20 to 24 °C (**Fig. 3**). However, at certain measuring points in the cold season, the indoor air temperature was exceeded at certain times during the day, when the temperature dropped below 18 °C or rose above 24 °C. In tab. 3 shows that the maximum allowable temperature is 26 °C. In this context, the environment can be characterized in terms of the thermal state as acceptable, but not ideal.

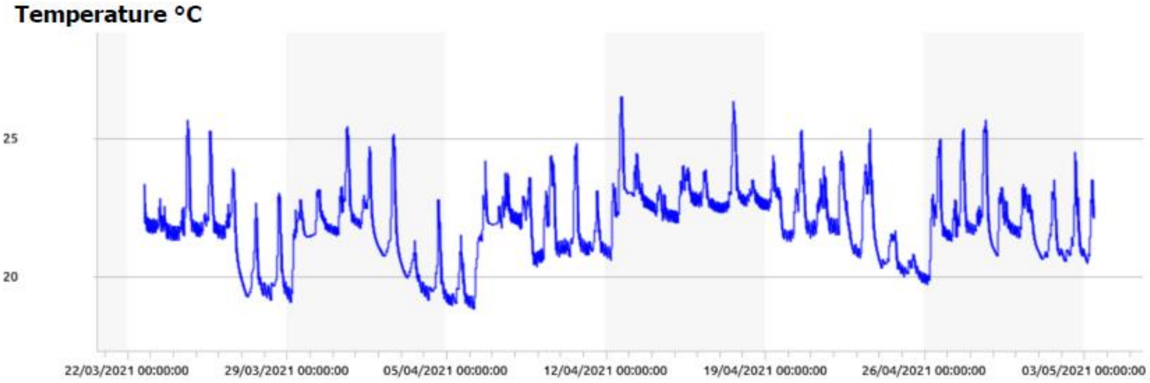

Fig. 3 - Graphs of temperature - Game room.

The humidity in the game room at the individual measuring points in connection with the requirements defined in legal and technical regulations was acceptable, as the relative humidity of the indoor air during the entire measurement period was in the range of 30 to 70 % (**Fig. 4**).

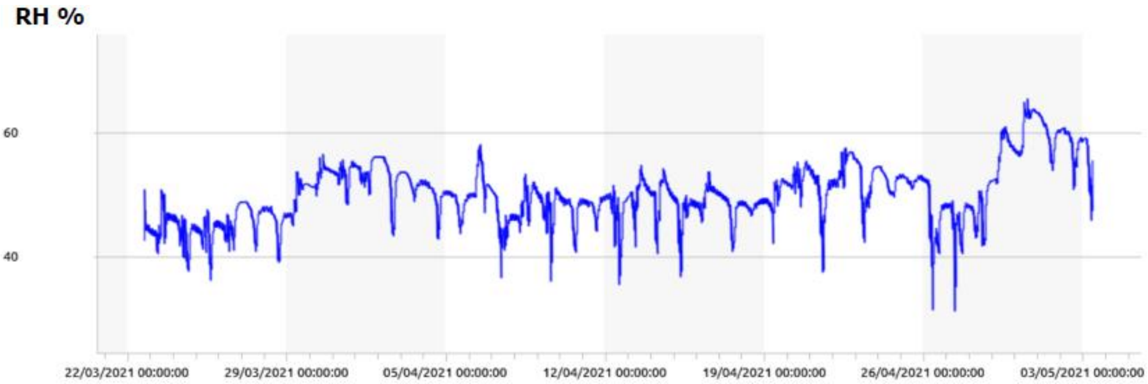

Fig. 4 - Graphs of humidity - Game room.

The quality of the indoor air at the individual measuring points by the requirements defined in the legal and technical regulations was partially acceptable, as at certain points the CO_2 concentration values were higher than the recommended limit value of 1500 ppm (**Fig. 5**) [8, 9].

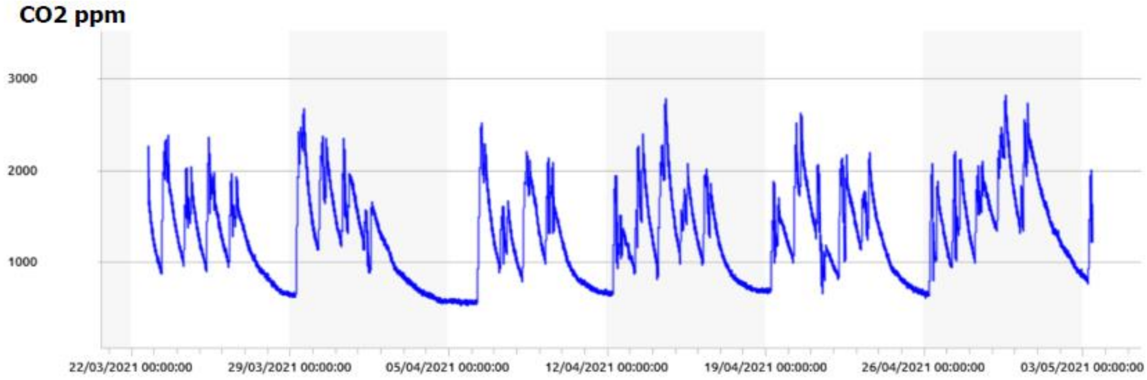

Fig. 5 - Graphs of concentration of carbon dioxide - Game room.

5. Conclusion

Some of the measured points show an acceptable state of both microclimate and indoor air quality, while others reach this state only in certain time intervals, but there are measured values where the state of the indoor environment is unacceptable. One of the solutions that can significantly improve indoor air quality in the school classroom is mechanical decentralized ventilation with a very unconventional location (under the sill) of the air handling unit. These are not local (room) ventilation units, this is a new solution that is still in the development phase.

6. Acknowledgement

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Data Statement

The datasets generated during and/or analyzed during the current study are available in the “Ulož.to” repository, https://ulozto.sk/file/XVZmKyN4RVpz/game-room-23-xlsx#!ZGWuZwR1MJSuMTZ1LwyvAmp1ZGHlraOJHx1zK3tkrxS2LmVl.