Proceedings of the World Congress on New Technologies (NewTech 2015)
Barcelona, Spain – July 15 - 17, 2015
Paper No. 160

Analysis of Microclimate in Public Buildings in North-Eastern Poland

Katarzyna Gładyszewska-Fiedoruk, Dorota Anna Krawczyk
Bialystok University of Technology,
Faculty of Civil Engineering and Environmental Engineering,
Department of Heat Engineering
Wiejska 45E, 15-351 Białystok, POLAND
e-mail: d.gladyszewska@pb.edu.pl

Abstract **–**Main parameters of indoor air quality could influence people health, fettle and ability to work. The research was conducted in a few public buildings located in Białystok, north-eastern Poland and included concentration of carbon dioxide, relative humidity and temperature. The tested buildings was composed of doctor's offices in 6 different medical practices. This kind of rooms should fulfil requirements concerning minimal air change rate and minimum sanitary standards: according to PN-EN 13779 standard:
- ventilation air stream as recommended by the ASHRAE, WHO, PN-EN 13779 standards;
- air change rate as mentioned by the Directive of the Minister of Health;
- CO_2 concentration limit according to ASHRAE, WHO, PN-EN 13779.

In November, only in few rooms air parameters were within the norms. In some offices the CO_2 concentration was above limit, mostly in offices with gravity ventilation system. In some rooms the indoor temperature was too low, whereas the air was too dry (in range 22.9-34.2%). In February, in all the offices in indoor air was dry, CO_2 concentration was exceeded (even 1463 ppm), and both air temperature and humidity were too low.
Moreover some measurement and surveys were taken in the cinema in Łomża during three working days. The recorded data showed that CO_2 concentration was significantly exceeded – 1943 ppm in second day of measurements and 2094 ppm in third one. It was connected with users number and lack of efficient work of ventilation system. The temperature was always lower than 20^{o}C and people complained about it. The relative humidity was in range from 40 to 58%, so as recommended 40-60%.
Another research was devoted to issues related to the microclimate and thermal comfort in a small office building.
In this case measurements included parameters such as indoor air temperature, CO_2 concentration, humidity, noise and lighting intensity. In all rooms during working days indoor air temperature was recorded in range from 19.8 to 26.9^{o}C, so as recommended, however in some people's opinion it was too low or too high. Relative humidity was in range 33%-46%. CO_2 concentration was low, only several optimal times level was exceeded about 469 ppm. Noise level was under 40 dB and light level about 500 Lx - 750 Lx.
The results of measurements and surveys allowed to analyze the microclimate in the public buildings. Proper indoor air quality is strongly important and legislative measures should be undertaken in order to work out a comprehensive system for evaluation of indoor air quality.

Keywords**:** carbon dioxide concentration, indoor air quality, natural ventilation, stack ventilation

1. Introduction

The amount and composition of air pollutants depend on both: the sources of emissions and way of distribution, These factors differ significantly for indoor environment in naturally or mechanically ventilated rooms and outdoor conditions (Krawczyk & Gładyszewska-Fiedoruk 2013). Microclimate is a synthesis of conditions that generate thermal environment in the room, so it changes dynamically in all closed spaces, depending on changes in values of one or more parameters these describe it (Berglund, 1980).

Microclimate is formed by many parameters like air purity, its chemical composition, indoor temperature, relative humidity, as well as the velocity of air or the temperature of the surrounding areas. All components of the microclimate have a huge impact on human mood, mental and physical performance, work efficiency and good health. Moreover microclimate determines the physiological processes, so its optimal conditions should be kept (Skwarczyński & Dumała, 2002). It is necessary to systematically provide fresh air to rooms, in impure areas after previous filtration. In most buildings with natural ventilation problems with maintaining proper indoor microclimate are connected with tight window frames which effectively block the flow of fresh air and reduce the effectiveness of ventilation. In case of rooms with mechanical ventilation problems are caused by poor quality of air filtration or too high share of recirculation stream. Indoor air pollutants can be divided into 3 groups:

- physical:
  - noise;
  - vibration;
  - ionizing radiation;
  - electromagnetic radiation;
- chemical:
  - Nitrogen dioxide;
  - Sulphur dioxide;
  - Ammonia;
  - Carbon monoxide;
  - Carbon dioxide;
  - Ozone;
  - Volatile organic compounds;
  - smoke;
- biological:
  - dust;
  - mites and saprophytes;
  - mould;
  - Mykotoxins;
  - Bacteria type Lagionella pneumophilis.

1. 1. Carbon Dioxide Concentration

The main parameter determining the indoor air quality is the concentration of carbon dioxide in residential and public buildings.

Table. 1. The carbon dioxide concentration limits (own study based on Nantka, 2000).

CO_2 concentration		Observed effect
mg/m^3	ppm	
1997	1000	Limit of CO_2 in rooms proposed by Pettenkofer (Pettenkofer, 1851, ASHRAE 1989, WHO 2000, PN-EN 13779)
2965-9885	1500-5000	Values observed in classes, cinemas, conference rooms
13840-19770	7000-10000	Level observed in submarines. It could start cyclical changes in the acid - base balance and reduce the hardness of the bone due to release of calcium into the blood
39540	20000	Could cause increased respiratory rate and headaches
118620-158160	60000-80000	Could cause paralysis
158160-197700	80000-100000	The loss of consciousness

In Poland there is no relevant legislation regarding the level of carbon dioxide concentration in the indoor air, however mostly 1000 ppm is considered to be recommended limit in the rooms and it is called maximum hygienic value.

When the carbon dioxide level reaches 2500 ppm (0.25%), it is regarded as dangerous for human health. In table 1 data relative to the risks depending on concentration of carbon dioxide in the air was shown. Table 2 shows the relationship between the quantity of carbon dioxide, oxygen consumption per person and the type of human activity.

Table. 2. Carbon dioxide and O_2 per person depending on activity level (own study based on Recknagel et. al, 2008).

Activity	carbon dioxide CO_2	oxygen O_2
	[litr/h]	[litr/h]
Relax	12	14
Activity level I	15	18
Activity level II	23	27
Activity level III	30	35
Activity level IV	above 30	above 35

1. 2. Humidity

There are two kinds of humidity, although during microclimate and air quality tests relative humidity is always used, because it characterize a part of water vapour content in the air, related to the maximum possible water vapour content at a given temperature. The level of humidity inside the room is determined by the emission of water vapour connected with human metabolism, the water vapour transport with the ventilation air stream, the diffusion of water vapour through the building envelope, its accumulation in materials or processes the phase change etc (Gładyszewska-Fiedoruk & Krawczyk, 2015). The relative humidity in most rooms should be in range between 30 and 70 %.

2. Analyzed Objects

The research was conducted in a few public buildings located in north-eastern Poland and included tests of a concentration of carbon dioxide, relative humidity and temperature. Results of chosen objects are presented below.

2. 1. Doctor's Offices

The first group of tested buildings was composed of doctor's offices in 6 different medical practices.

In Poland the Directive of the Minister of Health (2006) regulates the conditions which should prevail in all kinds of doctor's offices with regard to professional and sanitary standards to be kept in the rooms and by the equipment in a healthcare institution.

The Directive 2002 states that every room in a healthcare institution should possess a ventilation system that complies with the regulations of the building code (Regulation of the Minister of Infrastructure, 2009) and ensures that the air exchange rate is at least 1.5 per hour. The hygienic minimum in doctor's offices, just like in any other public buildings, is determined on the basis of PN-83/B-03430 and amounts to 20 m^3/h per person.

Each of the doctor's offices under investigation is located in Białystok, in north-eastern Poland, in eastern Europe in the temperate zone. It is inhabited by almost 300 000 people. Outside air is clean, because the carbon dioxide concentration is 380 ppm (Bogdan & Chludzinska, 2010; Krawczyk, 2014; Web-1).

The measurements were taken in summer so most windows were open during tests. The mean velocity of air was measured in the gravitational ventilation grates (Gładyszewska-Fiedoruk & Krawczyk, 2014). The minimum ACH established during the measurements amounts to 0.7 (fig. 1).

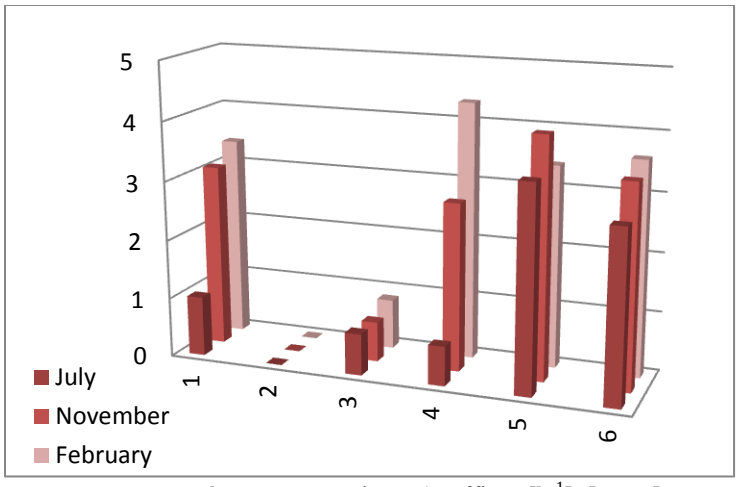

Fig. 1. Air change rate in doctor's offices [h^{-1}]; [ACH]

In November (fig. 2) only in few rooms air parameters were within the standards. In some offices the carbon dioxide concentration was above limit, mostly in offices with gravity ventilation system. In some rooms the indoor temperature was too low, whereas the air was too dry (in range 22.9-34.2%). In February, in all the offices in indoor air was dry, CO_2 concentration was exceeded (even 1463 ppm), and both air temperature and humidity were too low.

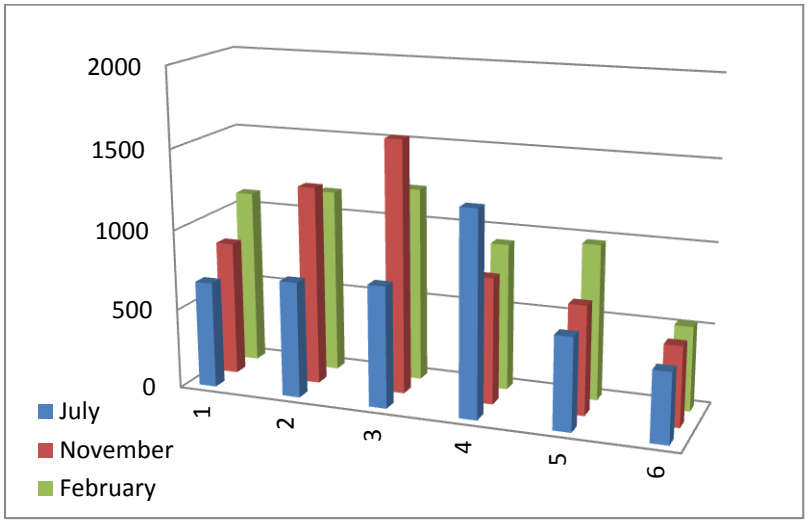

Fig. 2. CO_2 concentration in doctor's offices [ppm]

The results form measurements conducted in July showed that carbon dioxide concentration in 5 doctor's offices were lower than 1000 ppm. Only in room No4 the recorded values were higher, because air conditioning system was working and all windows were closed during tests.

2. 2. The Cinema

The tests of the indoor air quality were conducted in the cinema located in Łomża (north-eastern Poland) and indoor temperature, carbon dioxide concentration and relative humidity were measured. The results of first day of measurements are shown in figures 3-4.

The maximum level of carbon dioxide concentration was 1950 ppm (fig. 3). The relative humidity was in range 52-57% (fig. 4). Moreover people answered five questions about their feelings while watching a movie in the cinema. The results of the survey are presented in figures 5.

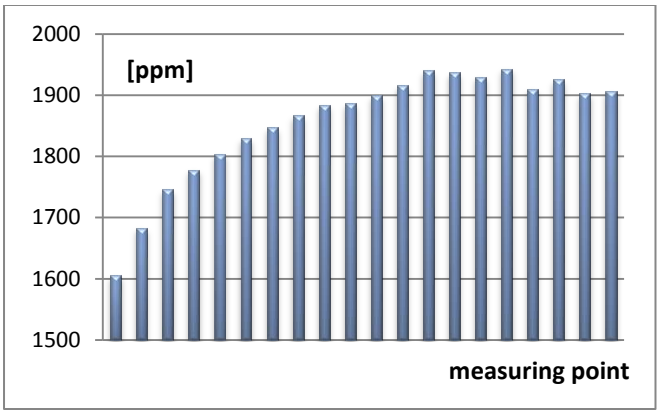

Fig. 3. CO_2 concentration in cinema

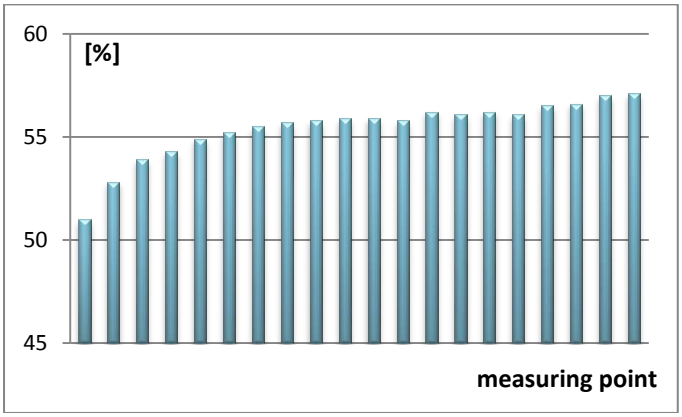

Fig. 4. Humidity in cinema

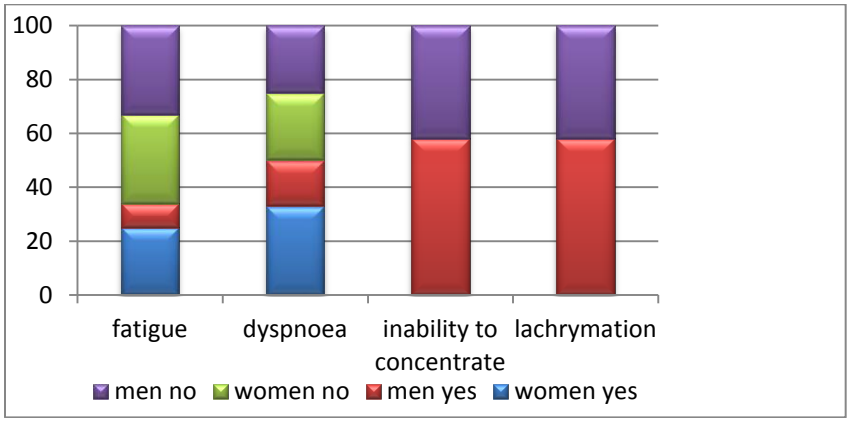

Fig. 5. The survey answers

2. 3. The Small Office

Tests of microclimate were conducted in the office building. In this case measurements included parameters such as outdoor air temperature, indoor air temperature, concentration of carbon dioxide in the air, relative humidity, noise and lighting intensity during the day and evening at the workplace.

The results of carbon dioxide concentration in 7 rooms are shown in figure 6, whereas figure 7 describes relative humidity level. Moreover average illuminance values are presented in table 3.

In all rooms during working days indoor air temperature was recorded in range from 19.8 ^{o}C to 26.9^{o}C, so as recommended, however in some people's opinion it was too low or too high. Relative

humidity was in range 33%-46%. Carbon dioxide concentration was low, only several optimal times level was exceeded about 469 ppm. Noise level was under 40 dB and light level about 500 Lx - 750 Lx.

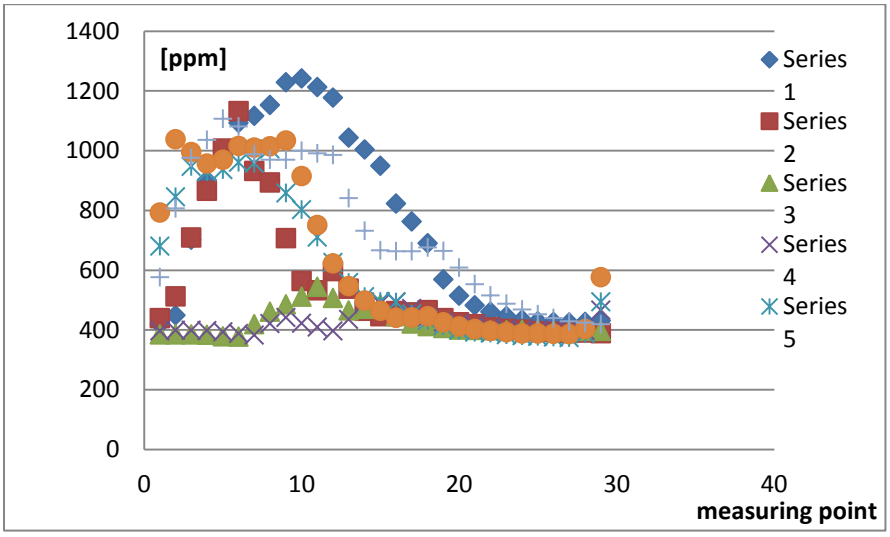

Fig. 6. Carbon dioxide concentration in small office

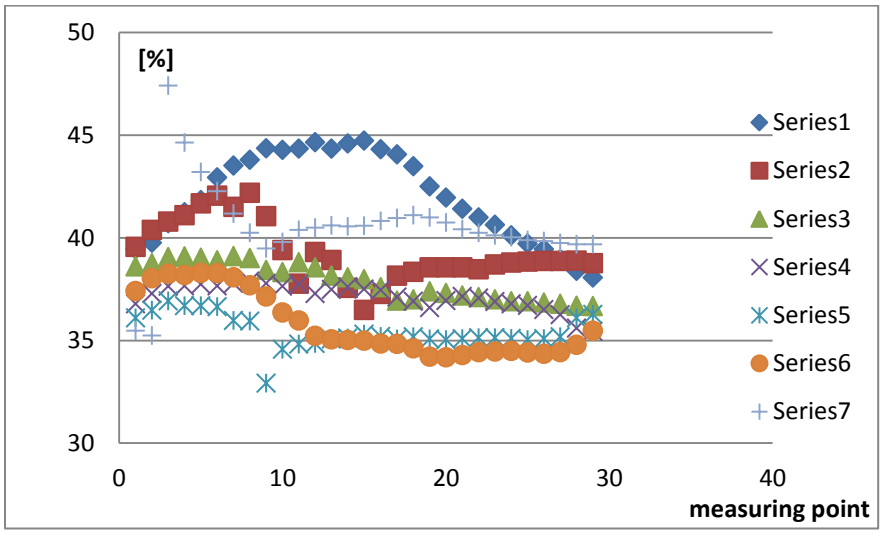

Fig. 7. Humidity in small office

Table. 3. Illuminance in working places.

Working place	Illuminance [Lx] – natural lighting	Illuminance [Lx] – artificial lighting
1	550	554
2	466	445
3	1250	411

Additionally surveys were made in two week periods and the chosen results are presented in figure 8. For a question "Are you glad of thermal comfort in the room?" people could choose the answers: 1- I am very disappointed, 2 – I am disappointed; 3 – I have no opinion,; 4 – I am glad; 5 – I am very glad.

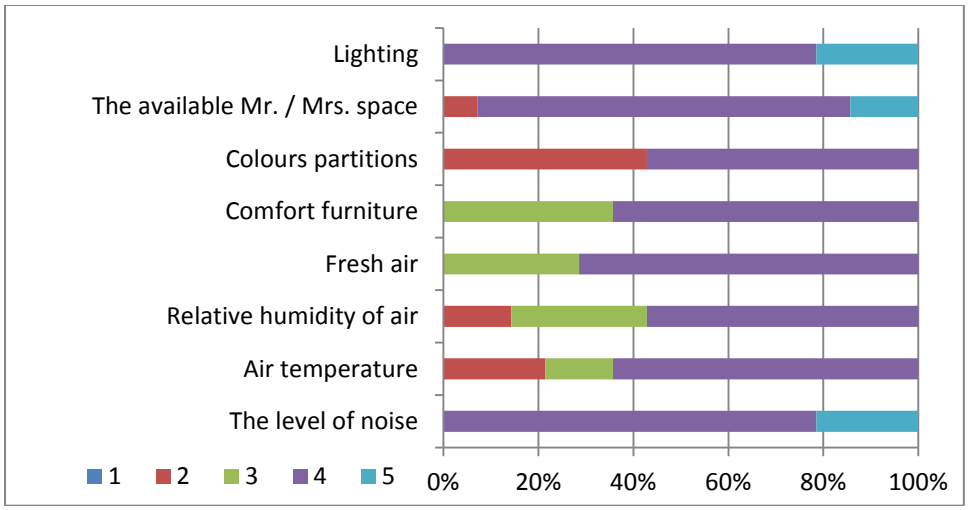

Fig. 8. Thermal comfort conditions

4. Conclusion

The results of measurements and surveys allowed to analyze the microclimate in the public buildings. Proper indoor air quality is strongly important and legislative measures should be undertaken in order to work out a comprehensive system for evaluation of indoor air quality.

In some cased it would be recommended to install the mechanical ventilation system to achieve better indoor air quality and microclimate in rooms.

Acknowledgements

This scientific project was financed within the framework of science research funds at Białystok University of Technology S/WBIIŚ/4/2014.

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