Anita Białek, Bade Koltuk
Structure and Environment 2021, vol. 13, (1), pp. 10-15, Article number: el 002
https://doi.org/10.30540/sae-2021-002

Structure and Environment
ISSN 2081-1500
e-ISSN 2657-6902
https://content.sciendo.com/sae
https://www.sae.tu.kielce.pl

sciendo

Kielce University of Technology

DOI: 10.30540/sae-2021-002

THERMAL COMFORT MEASUREMENTS IN THE ENERGIS BUILDING

BADANIA KOMFORTU CIEPLNEGO W BUDYNKU ENERGIS

Anita Białek*
Kielce University of Technology, Poland
Bade Koltuk
İstanbul Üniversitesi-Cerrahpaşa, Turkey

Abstract

In the paper the measurements of thermal comfort in the modern smart building "Energis" have been presented together with their analysis. The data have been obtained in the spring and the analyses of indoor air parameters as well as subjective responses of the volunteers have been conducted. Based on the performed studies it has been concluded that the people felt fine in the considered room (pleasantly warm, cool and comfortable) and described their feelings as acceptable and comfortable.

Keywords: indoor air quality, thermal comfort, thermal responses

Streszczenie

W artykule przedstawiono wyniki badań i analizę komfortu cieplnego w budynku inteligentnym „Energis". Dane eksperymentalne uzyskano w okresie wiosennym, a analiza dotyczyła parametrów powietrza wewnętrznego, jak również subiektywnych odczuć ochotników. W oparciu o przeprowadzone badania można stwierdzić, że użytkownicy czuli się dobrze w rozpatrywanym pomieszczeniu (przyjemnie ciepło i chłodno, a także komfortowo) i ocenili swoje odczucia jako akceptowalne i komfortowe.

Słowa kluczowe: jakość powietrza wewnętrznego, komfort cieplny, odczucia cieplne

1. INTRODUCTION

Smart buildings are a system in which the energy consumption of the buildings can be controlled automatically with the equipment inside the building in order to increase the energy efficiency. The most important task of the smart building is to ensure that the energy consumption of the building is at the lowest level without sacrificing user comfort. However, many times people complain about the conditions found in such buildings (which might also be caused by poor maintenance). Consequently, it needs to be determined if the complaints might be justified. Thus, the present paper aims to collect data and analyse them in order to conclude about the indoor conditions on a selected smart building located on the campus of Kielce University of Technology in Poland.

2. DATA ACQUISITION

The measurements of thermal comfort have been performed in the Energis building (Fig. 1) in the spring season.

It is located on the campus of the Kielce University of Technology and home to the Faculty of Environmental, Geomatic and Energy Engineering, is an example of a smart building. The Energis building, which was put into use in 2012, is located on Warszawska Street in the western part of the university campus. This building is a 7-storey building, while two of these floors are underground. The building has monolithic reinforced concrete structure. The outer walls are insulated with styrofoam, the inner walls are made of clay brick. The concrete flat roof is also insulated with styrofoam. A characteristic feature of Energis is the presence of the

*Kielce University of Technology, Poland, e-mail: anita_bialek@interia.eu

environment

Fig. 1. Photo of the Energis building. Source: own resources

BMS (Building Management System), which controls the building services (heating, ventilation, etc.) and a number of other systems that help to manage the whole facility. The building is one of the innovative, smart building examples by working with renewable energy by collecting solar energy as well as the energy accumulated in the ground and in the air.

Measurements were made in lecture room No 1.14 of the considered Energis building. Figure 2 presents the data acquisition unit on the tripod and located in the center of the room.

Thermal environment was assessed in the form of air temperature and velocity, black sphere temperature, pressure, CO_2 concentration, light intensity and relative humidity parameters. The people who were in the room while the mentioned parameters were measured with the device, filled out a questionnaire containing questions about the microclimate in the room. In this questionnaire, participants were asked to rate their current state and wishes for temperature, lighting etc. The purpose of conducting the survey is to allow people to express their thermal comfort and to compare the results of the survey with the measurement results. Age, gender, health status of the person and the current clothing should be considered before the survey that will affect the person's thermal comfort.

The measurements covered 15 people at the age of 22-38 years old, including 5 women and 10 men. The schematic of the room has been presented in Figure 3.

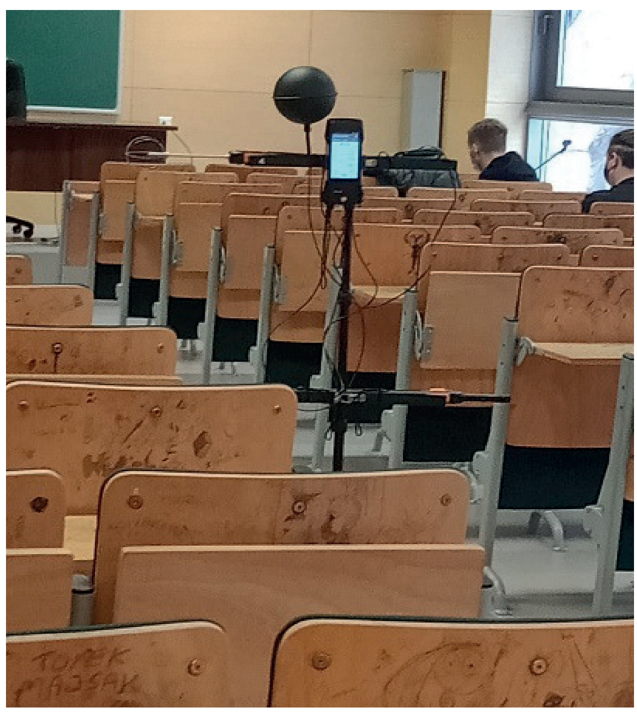

Fig. 2. Microclimate meter with the probes
Source: own resources

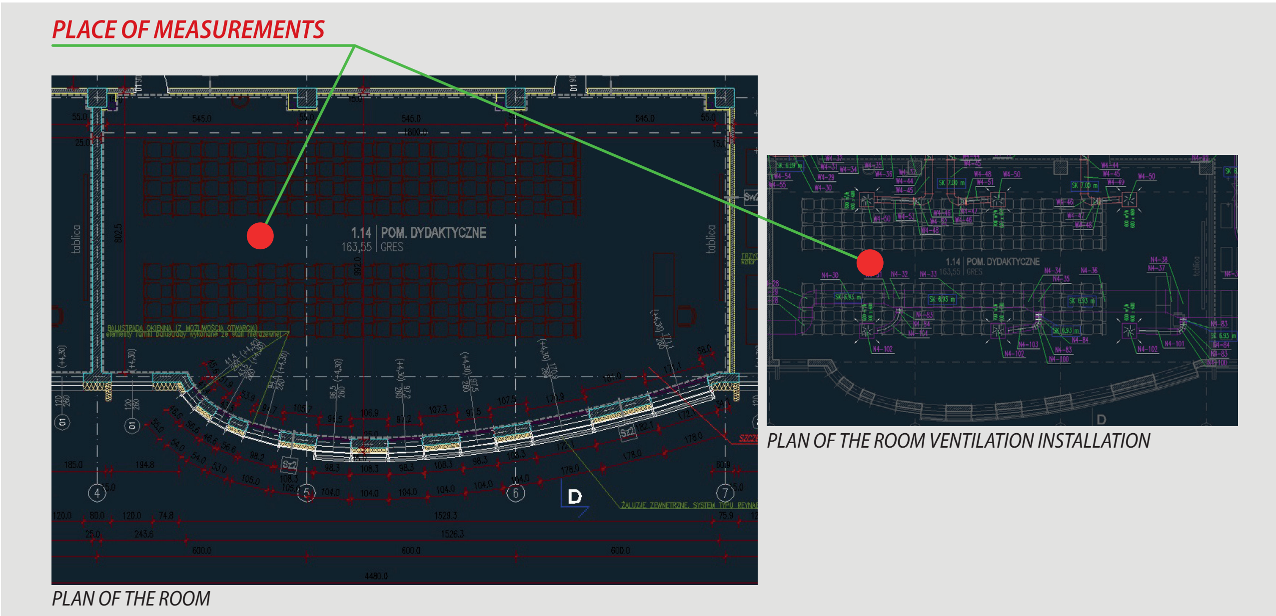

Fig. 3. Schematic of the room and the location of measurements (plan of the building adopted from: Puchała A., Budynek Laboratoryjno-Dydaktyczny Wydziału Inżynierii Środowiska Politechniki Świętokrzyskiej "Energis", Rzut I piętra Wentylacja i Klimatyzacja, 2010)

3. RESULTS OF THE MEASUREMENTS

During the tests a number of parameters were measured that changed with time of 5 minutes (Fig. 4). The first parameter of the four analysed is the temperature – the black line in Figure 4.

The parameter was maintained at the level of 23-25°C. For this type of room, the calculated temperature is +20 (for permanent residence of people without outer clothing, not performing continuous physical work) [1, 2]. The study was carried out in winter conditions (for a dressed person, the temperature should be between 20-23°C to ensure comfort), taking into account low physical activity in the room and maintaining the optimum indoor air humidity of 40-60% [3]. The control panel for the hall was set at a temperature of +22.8°C. The hall is equipped with an internal temperature control system via thermoelectric radiator heads with actuators. As shown, the room was heated to a temperature of approx. +24.8°C before the measurement. The parameter was striving to the set state (+22.8°C) and after the measurement time it reached +23.1°C. Thus, the heating/cooling system for the room reacted and works correctly.

The second parameter tested is carbon dioxide. In the lecture hall, mechanical ventilation was operating during the entire duration of the study. The room

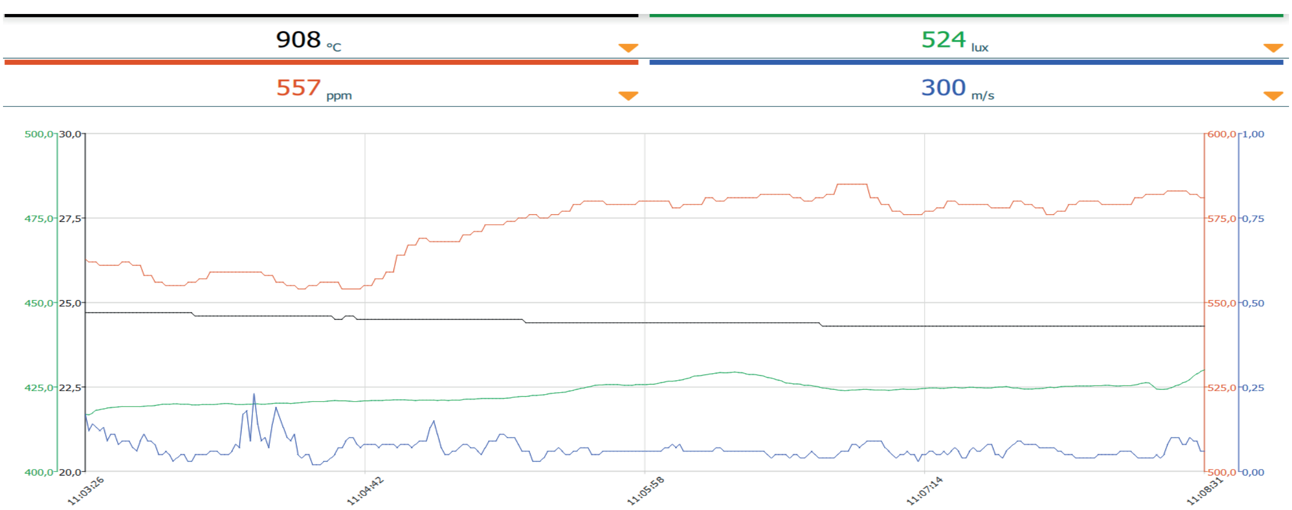

Fig. 4. Changes of selected indoor air parameters: air temperature (black line, left axis, °C), carbon dioxide level (red line, right axis, ppm), illuminance (green line, left axis, lx), air velocity (blue line, right axis, m/s)

was not equipped with a system for measuring the excess of permissible concentration of CO_2 in the room. There were no optical alarms and CO_2 sensors installed. When we talk about the freshness of the air in a room, we mean a value that is preferably close to the concentration in outdoor air between 350-450 ppm [4]. According to various international standards, the recommended CO_2 concentration for very good air quality is below 600 ppm. Poor air quality generally occurs when the CO_2 concentration exceeds 600-800 ppm, and poor air quality occurs when the CO_2 concentration exceeds 1000 ppm (increased respiratory rate). In the literature it is often interpreted that if the CO_2 value is above 1000 ppm this is a reason to improve the ventilation in the room and sometimes in the whole building. 1000 ppm = 0.1% which is the upper limit of freshness of the air according to WHO (World Health Organisation) and ASHRAE (American Society of Heating Refrigerating and Air Conditioning Engineers [5]) standards. Some standards, including those of the USA and the EU, set the concentration in indoor air at 800-1500 ppm, which corresponds to a ventilation air volume of 20-30 m^3/h per person [6, 7]. A CO_2 concentration of 5000 ppm (CO_2 molecules per million air molecules, 5000 ppm = 0.5% [8]) is taken as the safety margin during an 8-hour day in a working environment. However, this is a safety level and not a comfort or health level: Poland – MAC (Maximum Admissible Concentration) Limit; USA – TWA (Time-Weighted Average). Figure 3 shows how the CO_2 concentration level in the hall evolved. At the start of the measurement the index was at about 555 ppm, which is the quality of the fresh outside air. After the first minute we observe an increase in concentration. This increase is proportional to the duration of the measurement and the amount of carbon dioxide exhaled from the respondents' bodies. The measurement was terminated when the value of 580 ppm was reached. In 4 minutes there was an increase of about 25 ppm. Due to the short duration of the measurement it is difficult to say what indications would have been obtained after a 1.5 hour lecture. It can be assumed that a time of 90 minutes would be an increase of 562.5 ppm. Such assumptions can be made when the room is not equipped with a smooth mechanical ventilation air control system. Among others, through variable air volume controllers and when the air handling unit dedicated to the room is set at a constant volume. Otherwise, ventilation of the room should start when the concentration of 1000 ppm is exceeded. If ventilation can be mechanical, there should be a break during the lecture and manual ventilation, e.g. by opening doors and windows. The third parameter is the air velocity in the room. The quality of this parameter also reflects the comfort in the room. Air movement influences the intensity of heat absorption from the human body and thus directly influences the amount of heat released to the environment. Often, even the slightest movement can be perceived as discomfort. In most practical cases, the test result is considered positive when the air velocity is low (<0.2 m/s) and the difference between the radiation temperature and the air temperature is also low (<4°C) [9, 10]. The measurement was made with an air flow probe set at a height of 1.1 m above the floor level in the occupied zone [11]. This is the height of the clean zone – sitting (zone height 1.1 m) or standing (1.8 m). In fact, comfort conditions are only provided in this zone, which results in a reduction in the amount of cooling energy supplied compared with mixed ventilation. The measurement result (blue line in Fig. 3) shows that the air velocity in the room is almost imperceptible, below the value of 0.2 m/s [11]. The two momentary upward peaks are probably the result of movement, in close proximity to the device, of the person carrying out the measurement. For the rest of the test the result is well below the limit value of 0.2 m/s, showing no perceptible movement of the air inside the room. The fourth parameter measured is the illuminance of the room. The operational illuminance, i.e. the lowest value of the average illuminance recommended to be maintained during lighting operation in meeting and conference rooms, is 500 lx and should be adjustable. The readout value of the illuminance measurement is 420-440 lx. The measurement was made in the area between the students' seats, i.e. the illuminance of the immediate surroundings. The illuminance value should depend on, but may be lower than, the illuminance of the work area (visual task area). At the same time, it should ensure a homogeneous distribution of luminance in the field of vision. However, it must not be less than the illuminance values given in [12]. In the case of our hall, the illuminance condition has been met. In the case of lighting, the "ageing of the facility" is observed. The quality of the lighting in the hall commissioned in 2012 is already noticeable. In Figure 3 we see two peaks, in the second and fifth minute of the measurement. The reason for this may be the sunlight entering the room through unshaded windows. In order to eliminate this fact in the future, the measurement should be performed with all window openings in the room fully covered or during the night hours. The four parameters tested above did not show any deviation from the normative values for the measurements performed. Another parameter tested was relative humidity – its value was quite low – ranging from about 20% at the beginning to about 25% at the end of the measurements.

The state of comfort in the room was also questioned by the respondents. 15 participants took part in the survey: 5 women and 10 men. Thermal comfort is experienced differently by each person. It is therefore an individual and subjective feeling. There are, however, certain factors that influence the level of comfort perceived and make it possible to define acceptable values for thermal comfort. This is how the Predicted Mean Vote (PMV) index was defined [9, 10]. It describes the human thermal sensation on a 7-point scale. An increased value of room temperature (Fig. 4) is perceived by respondents. This fact is shown in detail in Figure 5. Namely, 60% of the female respondents find it pleasantly warm, while 40% find it pleasantly cool. On the other hand the results of the men's perception are as follows: 20% indicated that it is too warm, 30% pleasantly warm, 30% pleasantly comfortable, only 20% found it pleasantly cool.

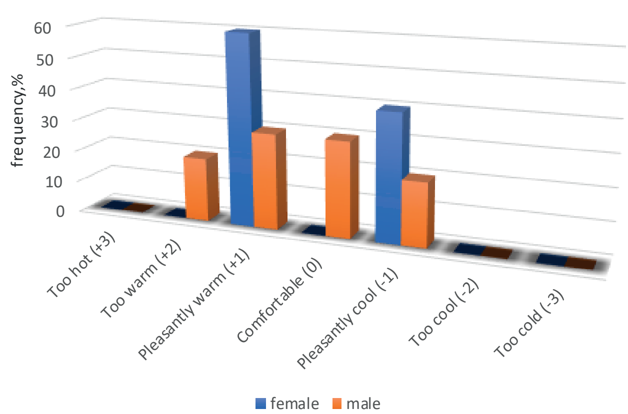

Fig. 5. Frequency of answers on thermal sensations: +3 – too hot, +2 – too warm, +1 – pleasantly warm, 0 – comfortable, –1 – pleasantly cool, –2 – too cool, –3 – too cold

A neutral feeling is considered to be the correct human feeling. The PMV value describing thermal comfort should therefore be between –0.5 and +0.5. As can be seen, this is a relatively narrow range, so it can be difficult to achieve in some types of room.

Figure 6 shows the evaluation of the room temperature. It describes the comfort and its acceptance by the respondents. 40% of both men and women found the room temperature comfortable, while 60% of both men and women found it acceptable. If the respondents had stayed longer in such a heated room (temperature of 24.8°C), the assessment would have been different, i.e. no longer acceptable.

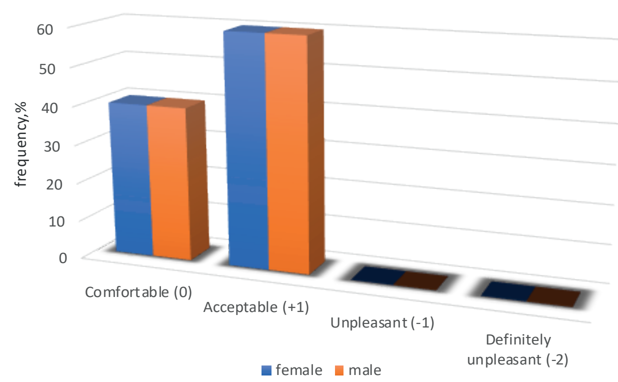

Fig. 6. Frequency of answers on temperatures felt: 0 – comfortable, +1 – acceptable, –1 – unpleasant, –2 – definitely unpleasant

Figure 7 shows the statistics of suggestions to make changes to the room. 40% of the interviewed women thought that the conditions in the room should remain unchanged, while as many as 60% of the women expect changes to be made. The quickest and easiest solution is to lower the temperature in the room. The suggestions made by men are in different proportions: 20% of men said that the room should be warmer, 60% no change, while 20% opted for an expected cooling in the hall.

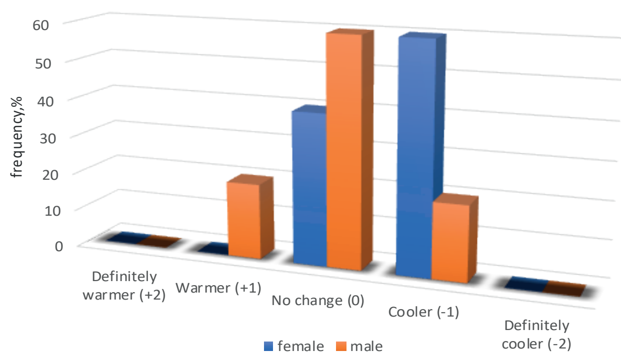

Fig. 7. Frequency of answers on thermal preferences vote: +2 – definitely warmer, +1 – warmer, 0 – no change, –1 – cooler, –2 – definitely cooler

So it is clear how both the temperature and the elevated carbon dioxide levels were perceived by the respondents. They are among the most important parameters affecting health, well-being and concentration especially in educational and training facilities.

Figure 8 shows the results of the respondents' opinions on the quality of lighting in the room. As a reminder, the place of the survey: a lecture hall, i.e. for a workplace there should be an illumination level of 500 lx. 20% of the women said the lighting was too bright, while 80% thought it was adequate. A similar opinion was expressed by men, 90% thought the lighting was adequate. Only 10% of the men said the lighting was too low.

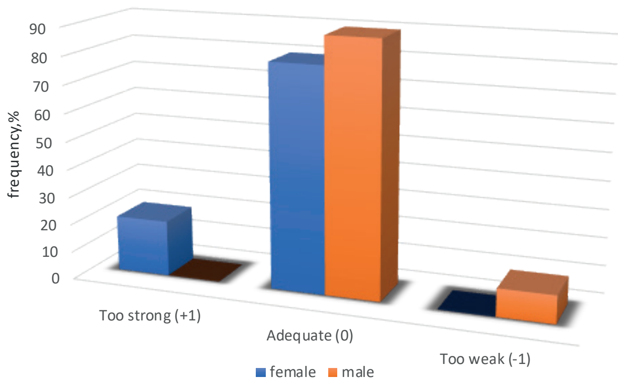

Fig. 8. Frequency of answers on the quality of indoor lighting: +1 – too strong, 0 – adequate, –1 – too weak

4. CONCLUSIONS

The survey and the questionnaire show how important room comfort is. The respondents felt that the temperature was slightly elevated, although this is individual. It is very difficult to maintain comfortable conditions in and out of a building for all occupants. Today, building owners and users strive to make buildings energy-efficient, cost-effective and, above all, comfortable. This is already happening at the stage of the construction process, where the designer, when drawing up the design, takes into account all these guidelines and expectations. In the course of the entire project and its realisation, newer and newer high-energy class buildings are constructed. The buildings are equipped with a full automation and comfort control system. The BMS system ensures and allows for full control and immediate reaction of the user to changes in internal parameters. All this makes it easier to meet the expectations and needs of occupants. Currently, especially in office buildings, there is a trend towards individual measurement of parameters in the working environment by employees. Awareness and expectations are rising compared to previous years. The requirements for permanently occupied rooms should be met satisfactorily for reasons of human comfort and economy. The assessment of the room conditions should be quick and clear and, if possible, improved immediately. Moreover, the analysis of thermal comfort in buildings equipped with renewable energy sources in Poland and abroad [13] is currently of significant interest. Thus, the subject has significant practical potential.

REFERENCES

[1] Regulation of the Minister of Infrastructure, 12 April 2002, on technical conditions to be met by buildings and their location (Dz.U. [Journal of Laws] from 2002 No. 75, item 690, as amended), § 134.1.
[2] PN-EN ISO 6946:2008 Building components and building elements. Thermal resistance and the coefficient of thermal transmittance. Calculation method.
[3] Regulation of the Minister of Labour and Social Policy Dz.U. [Journal of Laws] No. 79 from 1998 concerning the highest permissible concentrations of harmful for health in the working environment.
[4] Directive 2002/91/EC of European Parliament and the Council of 16 December 2002 on the Energy Performance of the Buildings.
[5] ASHRAE Standard Ventilation for acceptable Indoor Air Quality, 1989.
[6] PN-EN 12599 Ventilation of buildings. Test procedures and measurement methods for the acceptance of ventilation and air conditioning systems.
[7] PN-78/B-03421 Ventilation and air conditioning. Calculation parameters of indoor air in rooms intended for permanent human presence.
[8] Suś M., Premeco, published on 2015-09-04, https://premeco.oferteo.pl/analiza-stezenia-ditlenku-wegla-w-pomieszczeniu-biurowym/artykul/1093.
[9] PN-EN ISO 7730:2006 Ergonomics of the thermal environment. Analytical determination and inter-pretation of thermal comfort using the calculation of PMV and PPD and local thermal comfort criteria.
[10] PN-EN 15251:2007 Indoor environmental criteria including thermal conditions, indoor air quality, lighting and noise.
[11] PN-EN ISO 7726:2002 Ergonomics of the thermal environment. Instruments for measuring physical quantities.
[12] PN-EN 12 464-1: 2004 Operational illuminance.
[13] Holubčík M., Klačková I., Ďurčanský P., *Pyrolysis conversion of polymer wastes to noble fuels in conditions of the Slovak Republic*, "Energies" 2020, 13(18), 4849.