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COMPREHENSIVE STUDY OF THE MICROCLIMATE PARAMETERS IN THE RESIDENTIAL BUILDING

Abstract: *The* ***relevance*** *of the research lies in the development of the current question about the influence of microclimate quality on the efficiency of residential units.* ***The aim*** *of the study is to examine how the microclimate parameters affect the efficiency of residential buildings.* ***Findings.*** *The results obtained are essential for the design of energy-efficient and comfortable residential buildings. The scientific novelty and practical importance of research resides in the thorough study of microclimate in low-rise residential buildings. Microclimate deviation charts for residential buildings have been produced.*
Keywords: energy audit, heat-insulating cladding; heat insulation, energy efficiency, microclimate parameters, residential unit, complex thermal modernization

1. Introduction

The EU has made a commitment to reduce greenhouse gas emissions from 80% to 95% below 1990 levels by 2050 [6]. Residential buildings contribute significantly to greenhouse gas emissions. That's why energy consumption in buildings has become a major concern worldwide and policy makers endorse measures to improve the energy efficiency of buildings in order to promote sustainable use of energy [19].

The microclimate inside buildings is an essential factor for building energy efficiency. In recent years, people have faced several serious pandemic-related restrictions and stayed at home for a long time. Nearly everyone could feel how comfortable or uncomfortable it was to stay in his place. Temperature, humidity and concentration of carbon dioxide are factors that influence human well-being and comfort. Some indicators are very individual, for example, temperature. When 18°C is a fairly comfortable temperature for one person, the other feels warm, while it can be pretty cold for the third. The factors that may influence are human metabolism, clothes, air humidity, air velocity, and pollution. These parameters are connected. Thus, the analysis and monitoring of microclimate are essential and relevant since it directly influences human health.

The above topic is complicated and complex. The literature review demonstrates the relevance of the research subject matter. The research studies were focused on:

- analysis of thermal losses in buildings [3, 4, 9, 14, 18];
- analysis of energy efficiency and flexibility of the air conditioning and heating [1, 15];
- creating and improving calculation methods, algorithms to achieve optimal and effective energy consumption during peak hours [7, 8, 13, 17];
- experimental research using modern materials and studying their impact on increasing energy efficiency of buildings [11, 16];
- developing heat indicators and energy efficiency class limits in buildings [2, 5, 10, 12].

The research papers analyzed point to a lack of studies on the impact of the microclimate of residential buildings on their efficiency.

The aim of the research is to determine how microclimate influences the efficiency of residential buildings.

The subject of the research is the principles of microclimate changes in residential houses.

An object of the research is microclimate parameters and thermal failures of the low-rise residential building.

2. The methodology

Instrumental monitoring of microclimate parameters (temperature, relative humidity, carbon dioxide concentration) in residential buildings was carried out to analyze how microclimate affects the efficiency of houses [25].

Experimental facility - a residential house in Kherson (II climate zone). The building is located far from main roads on the outskirts of the city. Its total area is 69,9 m^2; its living space is 37,6 m^2. At the time of the experiment, the house was occupied by 6 adults and 5 pets.

The building envelope includes rough masonry (main building and extension №1) and shell masonry (extension №2, kitchen and bathroom). The walls of the house are insulated with 50-mm foam panels. The windows are PVC two-chamber double-glazed, one chamber is filled with argon. The floor of the main building is wooden with some crawl space. The floors in the extension buildings are cement. The roof is garret and double-pitched. The attic is not insulated.

Technical equipment. The measurements were taken with CO2HT-501 digital meter (see fig. 1). This measuring device can simultaneously take readings of temperature, relative humidity, and CO_2 concentration level. Necessary software allowed us to analyze the results obtained. The main technical characteristics are given in table 1.

Fig. 1. Digital meter CO2HT-501

Table 1

Technical characteristics of CO2HT-501 digital meter

Parameter	Value
Type of gas detector	stationary
Type of display pattern	digital
Types of gases	carbon dioxide (CO_2)
Measurement time	1 sec
CO2 measurement range	0-9999 ppm
Humidity measurement range	0.1 ~ 99.9% RH
Temperature measurement range	-10.0 ~ + 70.0℃
Operating temperature range	0-50°C

Measurements were taken in three premises (the living spaces and a kitchen). The meter was installed at 1-1,5m height and 1,5m from windows. The measurements were taken every 8 minutes during two 24-hour periods; total number of measurements is 360. We analyzed the results of microclimate monitoring in the living space, consisting of 2 living rooms without doors (19,4 m^2). The living room is for 2 people, at the time of the experiment, one person worked at the computer from 8:00 to 17:45. Over the 24-hour period there were constantly from one to four people in the room, as well as four pets. In addition, a gas heater was used.

Then we analyzed the results of microclimate monitoring in the service (utility) space, consisting of a hallway, a kitchen (no doors between), and a bathroom. The total area was 16,4 m^2. There was a gas stove in the kitchen. Over 24 hours, there were from one to five people in the premises. A gas heater was also in use. Ventilation ducts in the kitchen and the bathroom were in poor condition, and there was no exhaust ventilation. Hallway doors were mostly closed. There were five flower pots with indoor plants.

Dates of the experiment: Jan 4-5, 2021.

Weather conditions: 04.01.21 t = + 1°C, humidity 94%, overcast, no precipitation. 05.01.21 max. t = +4°C, min. t = +1°C, humidity fluctuated from 91% to 97%, overcast, no precipitation.

3. Results

The results of the microclimate monitoring are presented graphically in fig. 2 for living space and in fig. 3 - for a service (utility) space. The analysis of specific time intervals and extreme values are given in table 2 for living space and in table 3 for a service space.

According to Ukrainian standards [20–22], the specified temperature for a residential building is 20°C, an appropriate humidity rate is from 40% to 60% [21]. A recommended level of carbon dioxide is up to 1000 ppm when 1600 ppm is acceptable. To maintain the level of carbon dioxide within 1000 ppm, it is necessary to provide approximately 30 m^3 of fresh air per hour for every person. To keep it within 1600 ppm, it must give around 15 m^3 of fresh air per hour for every person [24].

We could observe that the temperature in the living space fluctuated from 18,2°C to 20°C, humidity – from 58,3% to 67,2%, and CO_2 concentration changed within 944 ppm - 2931 ppm (fig. 2).

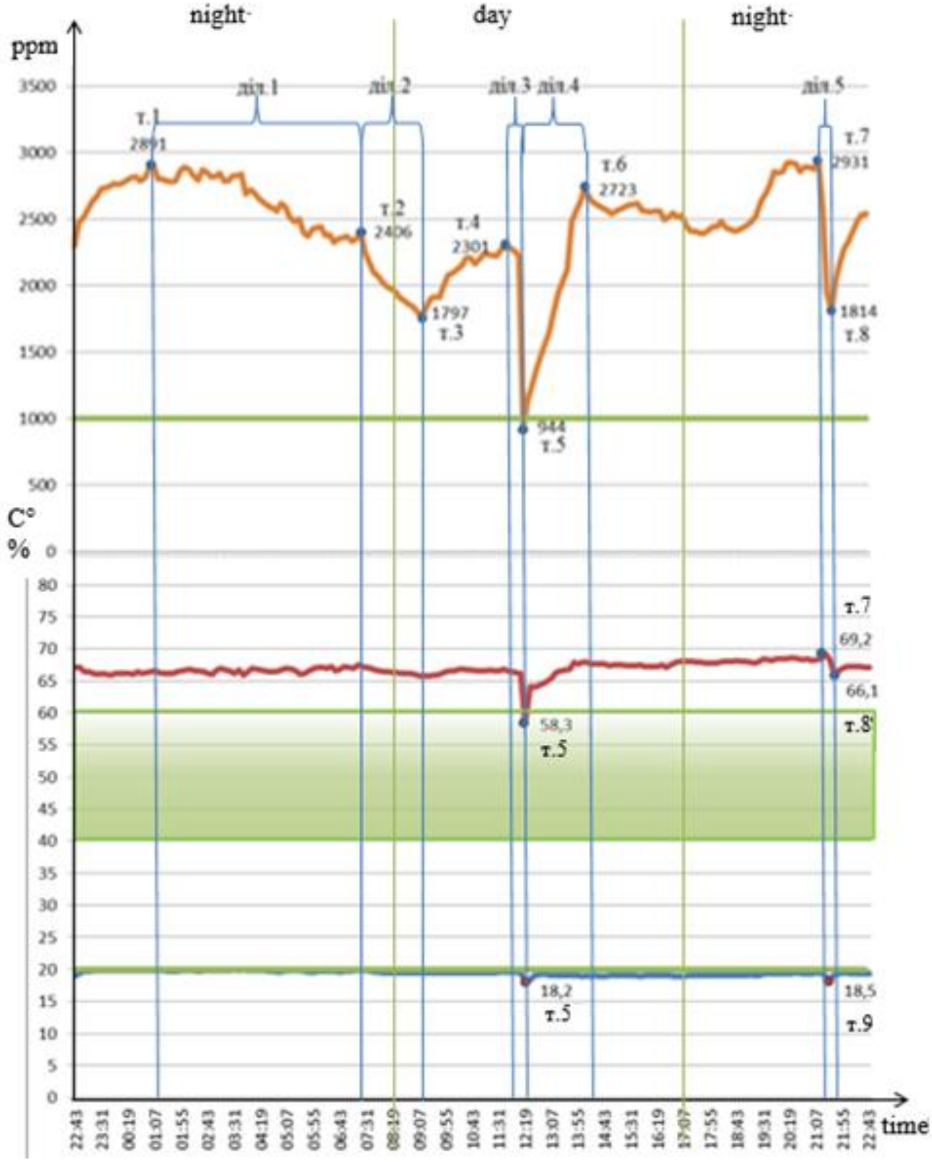

Fig. 2. Graphic representation of the microclimate monitoring in a living space: blue – temperature (°C), red – humidity (%RH), orange – CO_2 concentration (ppm), green – standard value

Table 2

Microclimate monitoring results (in the living space)

№	Time	ppm	%	°C	Analysis / Conclusions
point 1	00:59	2891	66,4	19,9	Max. value of CO_2 concentration per night.
point 2	7:23	2406	67,2	19,9	Min. value of CO_2 concentration per night.
point 3	9:07	1797	65,8	19,5	Min. value of CO_2 concentration without people.
point 4	11:47	2301	66,5	19,6	Max. value of CO_2 concentration before ventilating. Two people in the room.
point 5	12:19	944	58,3	18,2	The lowest value per day. The time of ventilating.
point 6	14:11	2723	67,9	19	Max. value after ventilating, two people in the room.
point 7	21:15	2931	69,2	19,5	The highest value of CO_2 concentration and humidity per day. Two people in the room.
point 8	21:39	1814	66,1	19,1	The values obtained at the moment of ventilating. Time was fixed in 9 min after the windows were closed.
point 9	21:31	1949	68,3	18,5	Min. temperature value during ventilation.
sector 1	6 hours 24 min	↓385	↑0,8	const	Drop in CO_2 concentration due to infiltration at night.
sector 2	2 hours 15 min	↓609	↓1,4	↓0,4	Drop in CO_2 concentration due to infiltration without people.
sector 3	15 min	↓1357	↓8,2	↓1,4	Ventilation. Conclusion: 15 min is enough to get standard values of CO_2 concentration and humidity.
sector 4	1 hour 52 min	↑1779	↑9,6	1,2↑	Increase in CO_2 concentration and humidity. Conclusion: it is appropriate to ventilate the room again at this time.
sector 5	15 min	↓1117	↓3,1	↓1	Ventilation. Lower values of CO_2 concentration and humidity at the time of ventilation do not reach the standard ones. In comparison with previous ventilation, the drop in values is almost the same over the same period of time, regardless of two people in the room. Conclusion: it is recommended to ventilate the room without people for 30 min in the evening.

We could observe that the temperature in the service (utility) space fluctuated from 19,2°C to 24,3°C, humidity – from 66,4% to 71,5%, and CO_2 concentration changed within 1323 ppm – 4087 ppm (fig. 3).

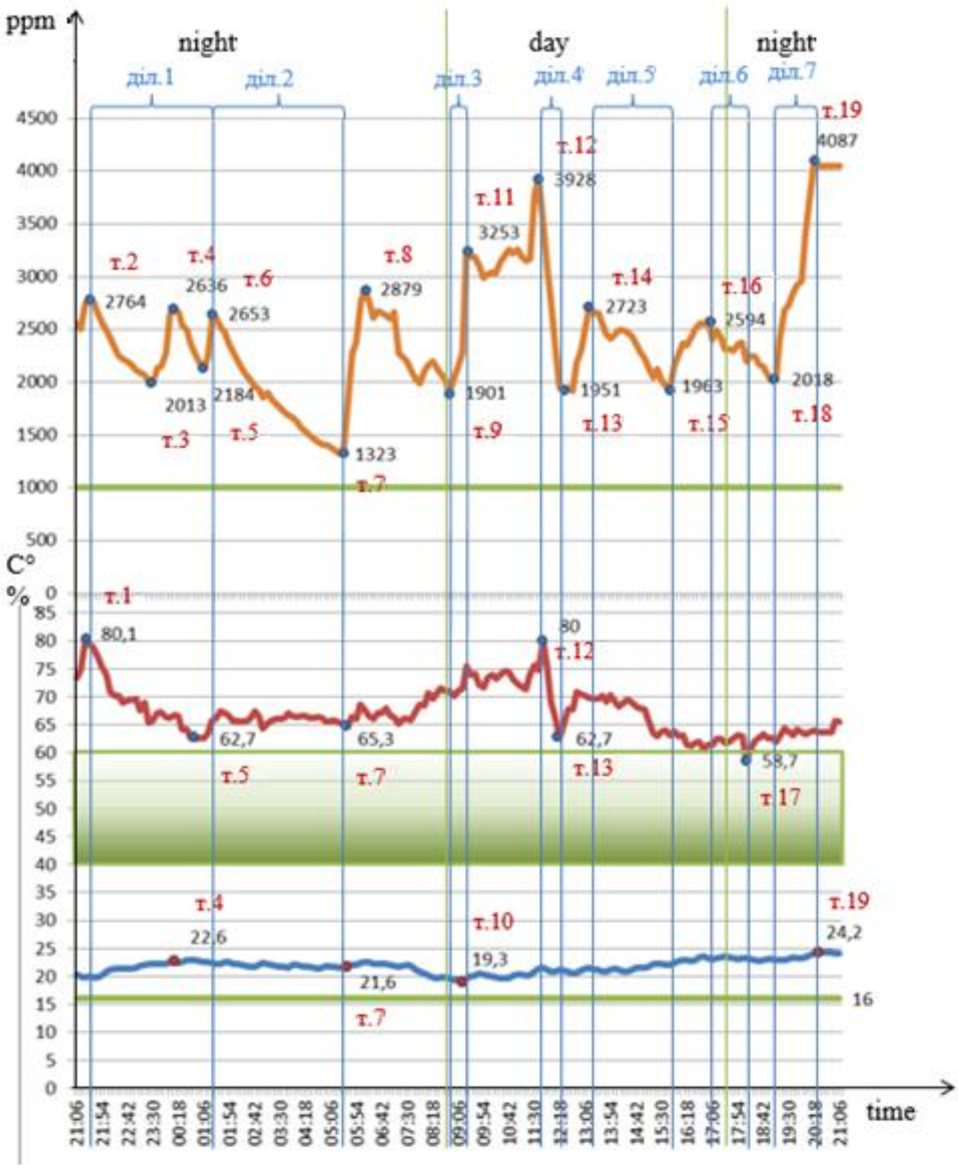

Fig. 3. Graphic representation of the microclimate monitoring in a serving (utility) space: blue – temperature (°C), red – humidity (%RH), orange – CO_2 concentration (ppm), green – standard value

Table 3

Microclimate monitoring results in the service (utility) space

№	Time	ppm	%	°C	Analysis/Conclusions
point 1	21:22	2741	80,1	19,9	The highest values of humidity per day.
point 2	21:30	2764	79,4	20	The time when the shower was used.
point 3	23:22	2013	65,4	22,2	No people, open faulty ventilation duct.
point 4	00:02	2636	66,2	22,6	The time when the shower was used.
point 5	00:58	2184	62,7	22,7	No people, open faulty ventilation duct.
point 6	01:22	2653	65,8	22,4	The time when the shower was used.
point 7	05:22	1323	65,3	21,6	The lowest value of CO_2 concentration. The effect of infiltration.
point 8	06:10	2879	67,6	22,6	Two people, gas stove in operation.
point 9	08:50	1901	71,1	19,6	Drop-in CO_2 concentration and temperature due to open front door.
point 10	09:06	2135	71,1	19,3	The lowest temperature value per day.
point 11	09:22	3253	75,5	19,6	Increase in CO_2 concentration and humidity. Gas stove in operation.
point 12	11:38	3928	80	21,4	Higher values of all three indicators. Gas stove in use, shower in use.
point 13	12:18	1951	62,7	21,2	Drop-in CO_2 concentration and humidity – ventilation.
point 14	13:14	2723	69,8	21,5	Four people in the premise.
point 15	15:38	1963	64	22,1	No people.
point 16	16:58	2594	61,4	23,2	Two people, gas stove in use, ventilation.
point 17	18:10	2201	58,7	23,3	The lowest humidity value per day.
point 18	18:58	2018	62,6	23,1	No people.
point 19	20:18	4087	64	24,2	The highest values of temperature and CO_2 concentration.
sector 1	3 hours 52 min	↓111	↓13,6	↑2,4	Time when the bathroom was used extensively. Decrease in CO_2 concentration and humidity due to the open faulty ventilation duct.
sector 2	4 hours	↓1330	↓0,5	↓0,8	Low values of all three parameters. The effect of infiltration.
sector 3	32 min	↑1352	↑4,4	const	Increase in CO_2 concentration and humidity due to gas stove in use. Conclusion: exhaust fan should be on when the gas stove is used.
sector 4	40 min	↓1977	↓17,3	↓0,2	Low values of all three parameters due to ventilation. They do not reach normal values. Gas stove in use. Conclusion: indoor air should be exhausted [23].
sector 5	2 hours 24 min	↓760	↓5,8	↑0,6	No people, appliances are switched off—the effect of infiltration.
sector 6	1 hour 12 min	↓393	↓2,7	↑0,1	Ventilation. Gas stove in use. Ventilation decreased the values of CO_2 concentration and humidity but not enough. Conclusion: indoor air should be exhausted [23].
sector 7	1 hour 20 min	↑2069	↑1,4	↑1,1	Three values increased due to gas stove in use and no ventilation. Conclusion: indoor air should be exhausted [23].

4. Conclusion

Instrumental monitoring of three micro-climatic parameters: temperature, relative humidity, and carbon dioxide concentration in Kherson's residential home was carried out.

Based on the results obtained, it was found that only one parameter, which is the temperature of indoor air, meets current standards. On the one hand, the outside walls of the house were insulated, and the windows were replaced with PVC double glazed ones to provide energy efficiency. On the other hand, the tenants of the house have reduced the natural ventilation time in order to save heat energy. All the measures taken contributed to a higher rate of relative humidity - 70-80% (standard values - 40-60%) and CO_2 concentration- 3000 – 4000 ppm (standard value - not more than 1000 ppm). This last parameter gives the house known as "building-related illness" (from 1500 to 5000 ppm), which adversely affects the health of tenants.

The monitoring has shown the importance of a comprehensive approach to the thermal renovation of buildings. A mechanical supply and waste ventilation system with heat recovery is required for the insulation of the building envelope.

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