Spatial Conditions and the Climatic Comfort of the Micro-Interior - Selected Issues

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Abstract: The article presents the results of research on the evaluation of the variability of selected climatic factors such as the temperature, gust and speed of wind in different locations (urban and extra-urban zones). The conducted research allowed to formulate a preliminary conclusion that the degree of openness of the micro-interior and its morphology has a direct impact on the microclimate of urban interiors. The results of the analysis led to the assumption that further research may confirm the close relationship between spatial and climatic conditions, and thus these observations may be important (while continuing the research and, consequently, confirming the conclusions) for the design practice in striving to improve the quality of the housing environment.

Keywords: Analysis of climatic conditions, Analysis of spatial conditions, Climatic factors, Spatial planning.

1. INTRODUCTION

One of the most urgent needs of the modern man is to ensure the best possible living conditions. They are shaped by appropriate functional and spatial solutions and micro-climate. The Authors refer their considerations and observations, to the assessment of climatic conditions, taking into account the variability of the parameters of selected climatic factors depending on the chosen location - urban and extra-urban zone – as well as the spatial arrangement (scale of buildings, distances between buildings, proximity to high green areas, etc.). Existing climatic and spatial-functional conditions make it possible to describe and feel the housing area as "healthy, comfortable and alive", that is, one in which each of us would like to live [1]. The micro-climate and the morphology of the area in question are important for each of these concepts.

Climatic factors and their values directly affect the quality of the housing environment. It allows for a discussion about the impact of spatial conditions on changes in the value of climatic factors, and thus also the climatic conditions of the place. An area which cannot ensure ventilation, interior lighting or, in the case of too much insolation, shading, will never be considered a comfortable living environment.

J. Kobylarczyk [2, 3] explains in detail the issue of solar radiation in residential areas and points out that the form of the building itself and the distance between buildings, including their height, have a direct impact on the amount of shading of the building's wall. In her work [5] she presented an analysis of the intensity of insolation in selected residential areas, including the time of the shading. The simulations showed exactly how the location in relation to the directions of the world, the height of buildings and the distance between them change the conditions of insolation of the area, but also the access of natural light to residential interiors. These issues are important for the subject of this article, as they confirm the purposefulness of conducting further research on the analysis of the impact of spatial conditions on the climatic comfort of a place. The indicated publication concerned only the analysis of the object's exposure to solar radiation or shading. The form and scale of buildings were considered among the elements shaping the spatial conditions of housing estates. In this article, the Authors took into account the different distances between the objects, noting that the location of objects in the urban interior also influences such climatic factors as temperature and wind speed. The fact that we influence many elements and factors shaping the morphology of a city or its smaller structures is also important. It is human activities that have already largely changed environmental conditions, and thus also climatic settings.

The changes of the airflow depending on the location of the buildings are described in detail by, among others, K. Klemm [4] distinguishing two characteristic areas - the area of overpressure and the area of under pressure. Additionally, K. Zielonko-Jung

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[6] in his analysis of the wind flow, which was based on the study by A. Flagi takes into account the height and form of objects, presenting the effects of constricted flow, sucking in, elongated building, flowing whirlwind and opening. These works describe phenomena without relating them to specific locations. They show general knowledge about the influence of buildings and their forms on the phenomenon of ventilation. The Authors expand this knowledge with the indication of differences in the parameters of climatic factors in the urban and non-urban zones. Due to the research carried out, these differences were described by means of values - numerical data.

The study by J. Fortini [7] is another important literature item for the analysis of the impact of spatial conditions on ventilation. It shows the degree of freedom of airflow depending on the morphology of the area. The authors of the article also took into account the existing conditions, additionally indicating the height of objects and the location of high and low greenery, as well as the changing values of parameters not only of wind - its gusts and speed, but also values related to temperature and humidity.

Progressing climate changes are one of the most serious phenomena that accompany cities and rural areas. Concern for the condition of the natural environment is in line with new design trends, as well as those related to spatial planning. The aspirations aimed at improving living conditions are accompanied by the ideas of cities of the future, smart cities. They are to provide their residents with comfort. It should be noted, however, that the desired effect can be achieved with the adaptation of the space to the prevailing meteorological conditions at a given time. In the case of objects, many intelligent solutions are already common. However, when it comes to areas it should be emphasized that adapting their spatial solutions to the climatic conditions requires long-term observations. The flexibility of solutions and the information system, which is an indispensable element of the functioning of a smart city, allow taking into account weather and climate changes by cities, non-urban spaces and their smaller structures. The achieved conditions would then allow the environment to be assessed as well designed.

According to R. Rogers [8] "A well-designed environment inspires the people who live in it, while badly designed cities brutalize their inhabitants (...) We shape cities, and they shape us." Following this thought, it should be stated that each of us has some influence on the present and future image of the city, the conditions they will provide and whether life in them will be inspiring. The feeling of shared responsibility for the city seems to be a key issue in taking actions to improve the quality of the housing environment. In this regard, the search for study tools and relationships between functional or spatial conditions and the microclimate should be perceived as one of the priorities.

Although the research tools used by the Authors are common, they are used relatively rarely to determine the impact of spatial conditions on the microclimate. The time scope of these studies, however, requires an extension in order to be able to formulate objective conclusions and recognize that the adopted research method is sufficient. Nevertheless, the described research constitutes the basis for conducting activities aimed at sensitising society to environmental problems, including climate change, taking into account the principles of social participation in spatial planning. This problem has been carefully researched by C. Broto, E. Boyd, J. Ensor [9] who planned to implement their observations for the climate change in Maputo, Mozambique. The authors of the study considered the presented issue as worth considering in further research and analyzes.

The results of the research may prove that it is necessary and possible to adapt urban spaces to climatic conditions. This opinion is shared by the authors of the publication entitled *Meteorological information for climate-proof urban planning - The example of KLIMPRAX* [10] who prepared simulations of climate changes in Wiesbaden and Mainz taking into account their current development and compared with the situation when their further growth would not take place. The results of the observations showed that the value of climate indicators in the summer period increases in areas with intensive development. It is influenced by the size of cities, the degree of their development and climate changes. In order for the results of the analysis to be translated into practical action, it is necessary to involve climate specialists, planners and city agencies.

The intention of the Authors was not to analyze the climatic conditions in selected cities, as in the case of the indicated publication, but to compare, inter alia, changes in meteorological conditions shaping the microclimate that occur in the urban and extra-urban zones within residential areas. However, what is important in both cases is the need to use digital tools

for the purpose of the research. This article is a preliminary supplement to the research results on the city scale by using a smaller scale related to selected areas.

An important literature item for the discussed subject matter is the publication by R and E. Kalbarczyk [11]. The researchers presented the results of long-term observations that lasted from 2005 - 2018. The research was carried out in the winter, and its aim was to show the relationship between air pollution and changes in meteorological conditions.

The authors of this article, as it was emphasized earlier, chose both urban and non-urban areas. It should be noted that it differs not only in the morphology of buildings but also in the level of development and the state of air pollution. It can be assumed that in the non-urban area the risk of air pollution is lower. The areas are also less developed. Therefore, it can be expected that the observations of the authors of the indicated publications complement each other.

S. Shareef and B. Abu-Hiijleh [12], who studied this problem by observing changing temperature parameters in a hot climate, writes more about the influence of geometrics and morphology of urban buildings on climatic conditions. The problem was described with regards to the change in the orientation of objects and the differentiation of the height of buildings within the city block. I was possible to formulate the conclusions due to the application of the ENVI-Met 4.1 software simulations. As shown by the results of the analyzes, the orientation of buildings is the most important factor that influences thermal conditions. Also, the introduction of changes in the height of buildings along the short axis of the city block is a factor that reduces the air temperature in the NW-SE orientation by 1.1 °C.

The authors of this article took into account not only the value of the temperature but also the parameters of gusts and wind speed, which changed depending on the distance from the building wall, not only in urban conditions but also outside the city. It should be emphasized that the density of buildings is one of the factors shaping the spatial arrangement and morphology of residential areas both in the city and outside it.

The main aim of the work is to demonstrate the importance of urban climatology in the spatial planning of high-quality residential areas. Another objective is to demonstrate the close relationship between the spatial conditions (they are provided in detail in Table **1**), taking into account the specified distance between the buildings (by placing the research stations at a specific distance from the building wall) and the micro-interior (temperature value, gust and speed of the wind) as well as to verify the research method.

The research also made it possible to achieve another goal, which is to show differences in the selected climatic factors between the extra-urban and urban areas. However, the results of the described Authors' observations in this regard should be treated as preliminary, constituting the beginning for further, much more extensive research. The conclusions are based on the daily survey (6 days in total), while is necessary to analyze the scope of the discussed issues in a much wider period.

2. RESEARCH METHOD

Two research methods were used for the purpose of the work. The first one consisted of the analysis of theoretical material - the analysis of the current state of research in the field of assessing the impact of spatial conditions on climate change in selected residential areas. The second method used in the study is the analysis of the daily measurement of temperature, gusts and wind speed in a selected area of extra-urban and urban zones, with the application of the *Easyweather* program.

Table 1: Conditions in the Research Areas (Authors' own study)

Spatial Conditions	Lubień – Extra-Urban Area	Kraków – City
The location of the object in the vicinity of which the research was conducted in relation to the directions of the world	East-West North facing station	East-West North facing station
Height of the object in the surroundings of which the research was conducted	4 storeys	3 storeys
The openness of the terrain	The area is open to the west	The area is closed on all sides

The research results were processed graphically. The study takes into account the existing conditions that determine the spatial configuration of the research areas. The following were taken into account: the number of storeys of the object in the vicinity of which the research was conducted, the degree of openness of the area, the presence of high greenery and the location in relation to the directions of the world (Table **1**).

The following research parameters were adopted:

- research location - city / extra-urban zone,
- the openness of the area,
- location of measurements taking into account the directions of the world,
- location of meteorological stations within the assumed distance - 2 meters from the wall of the facility.

The factors taken into account are not the only ones that should be included in the research on micro-interior climate. As most of the aspects not mentioned were the same for both locations, only those that indicate differences (apart from the location of the object in relation to the directions of the world, in the environment where the research was conducted) were listed.

Scenario No. I assumed the start of measurements on May 28, 2020, at 9:00 a.m. The duration of the research was two days. Since the time scope of the research was not extensive, the results and conclusions should be treated as preliminary. The village of Lubień, located 15 km from the nearest city of Myślenice (Małopolskie Voivodeship, Poland) was selected as the research location. The meteorological station SBS-WS-200 was used for the tests. It was placed 2 meters from the wall of the building, at a height of 175 cm. The location conditions assumed limitations - on the southern side, a wall of trees 20 meters from the meteorological station; on the northern side, the terrain was 2 meters open (the meteorological station was located at this distance from the wall); on the eastern side, the terrain was limited by a forested area located 10 meters from the measurement site.

Scenario No. II assumed the start of measurements on June 28, 2020, at 9:00 a.m. The duration of the research was two days. The Kraków downtown zone (Rakowicka Street, Małopolskie Voivodeship, Poland) was selected as the research location. The meteorological station SBS-WS-200 was used for the tests. It was placed 2 meters from the wall of the building, at a height of 175 cm. The location conditions assumed limitations - on the southern side, a wall of trees 7 meters 60 centimetres from the weather station; on the northern side, the openness of the area reached 2 meters 60 centimetres; on the eastern side, the area was limited by the wall of the facility located 15 meters away, and on the west side- the wall of the building- the station was 2 meters away from it.

The methodology of the research allowed for a comparative analysis of the results for both locations. They can be treated as complementary to the studies carried out so far in this thematic area and preliminary to obtain conclusions that can be used in the future for the design of high-quality residential areas.

3. RESEARCH RESULTS

The results of the research carried out in Lubień and the downtown area of Krakow (Rakowicka Street) with the use of the SBS-WS-200 meteorological station 2 meters away from the building's wall are as follows:

The results of studies carried out in the extra-urban area, where the area is more open, indicate higher and more frequent temperature fluctuations in the time range 9:00 a.m. - 4:00 p.m. After 8:00 p.m., another decrease can be observed. By 8:00 p.m. the

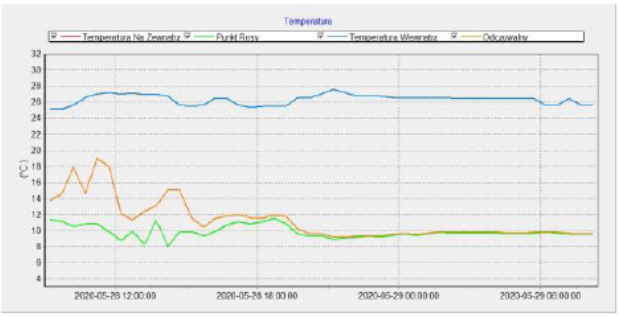

Figure 1: Temperature distribution (Lubień), Own study.

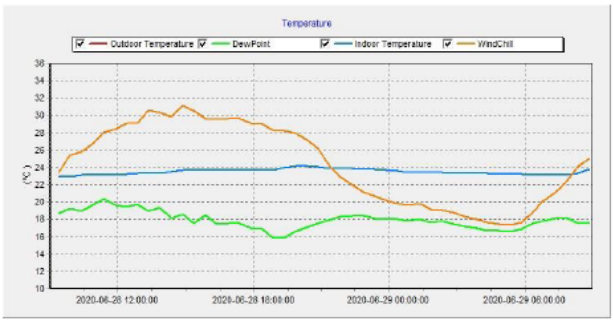

Figure 2: Temperature distribution (Kraków), Own study.

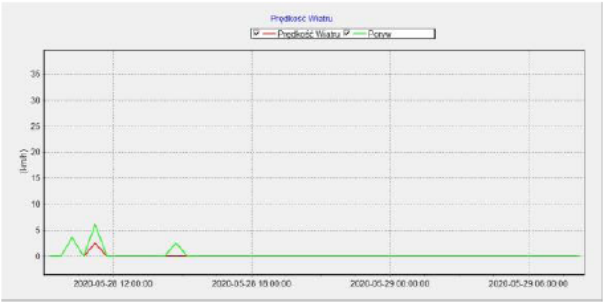

Figure 3: Wind speed and gusts (Lubień), own study.

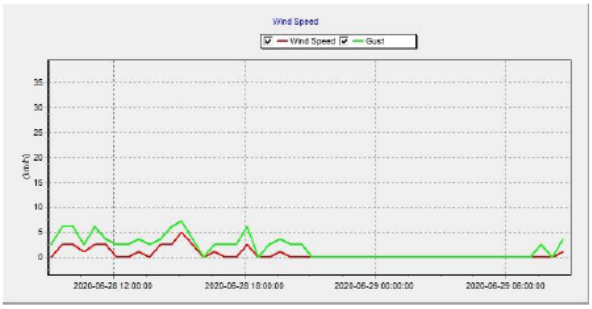

Figure 4: Wind speed and gusts (Kraków), own study.

temperature dropped to 9 degrees and remained at this level all night.

In built-up areas, temperature fluctuations are less frequent, although its fall in the evening hours is much higher. The highest temperature value was recorded at 3:00 p.m. - 31 degrees, and the lowest 17 degrees at 11:00 p.m. The temperature dropped by as much as 14 degrees. It should also be noted that the temperature in the city is much higher than in the non-urban area.

The measurements of wind speed and its gusts in the extra-urban zone (Lubień) showed that they most often occur in the time interval 9:00 a.m.- 4:00 p.m. Although the area is less sheltered than in typical urban areas, the wind does not reach any speed in the evening and night hours.

In the research area in Krakow, there are much more frequent and violent gusts of wind. Also in the evening hours (after 8:00 p.m.) and at night, the wind does not reach any speed.

The same tests were carried out in the above-mentioned locations with the use of SBS-WS-200 meteorological stations placed at a distance of 2, 3 and 4 meters from the building's wall. The test results were almost the same in the case of the distance of 2 m and 3 m (the results were presented for the case with the distance of 2 meters. The comparability of these results with the results at the distance of 3 meters should be assumed). The differences occur when the distance between the location of the meteorological station and the building wall is increased (4 m). Then the greater fluctuations in temperature and wind speed take place.

4. CONCLUSION

The conducted research allowed to achieve the intended goals of the work. They showed the impact of spatial conditions on changes in the parameters of selected climate factors. For this purpose, the study took into account different distances of the meteorological station from the walls of buildings in order to show that the distance between buildings is important for the microclimate of the interior and thus the comfort of the living environment. Therefore, it can be concluded that taking into account indicated distances has a direct impact on the shaping of a high-quality housing environment. The close relationship between the spatial conditions (distances between buildings, the scale of buildings, proximity to wooded areas) and selected climatic factors of the micro-interior (the value of temperature, gust and wind speed) was possible to observe due to the chosen research locations with different degrees of openness. The research method and the tools necessary for its implementation were also initially confirmed (due to the short period of the research).

As it was previously emphasized, the research carried out by the Authors should be perceived as preliminary. In order to formulate objective conclusions, it is necessary to extend the Authors' analyzes and observations in the scope of the discussed issues to a wider time span. What was additionally observed are higher values of gusts of wind with a simultaneous increase of its speed. It should also be noted that the time of occurrence of fluctuations in the range of wind speed and gusts occurred at the time when the temperature value increased. These fluctuations were more frequent - in terms of winds in the city, and the temperature in the extra-urban zone.

The differences in the parameters of selected climatic factors were visible with increasing the distance of meteorological stations from the walls of the objects, while for a distance of 2 and 3 meters these differences were practically non-existent. Only when the distance was increased to 4 meters, it was possible to observe greater fluctuations in temperature and wind speed. This information can be useful in practice, that is in planning residential areas, with particular attention to creating a convenient spatial layout (height of

buildings, the distance between buildings within a given housing structure).

These observations, and their confirmation by further research, may turn out to be useful in shaping a high-quality housing environment.

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