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Justyna Zapart

INFLUENCE OF THE TAILING POND "ŻELAZNY MOST" ON LOCAL CLIMATE

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Autor
Justyna Zapart

Opiniodawca
prof. dr hab. inż. Jan Żelazo

Redaktor merytoryczny
dr hab. inż. Krzysztof Pulikowski, prof. nadzw.

Opracowanie redakcyjne
Magdalena Kozińska

Korekta
Elżbieta Winiarska-Grabosz

Łamanie
Halina Sebzda

Projekt okładki
Krzysztof Wyszatycki

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WYDAWNICTWO UNIWERSYTETU PRZYRODNICZEGO WE WROCŁAWIU
Redaktor Naczelny – prof. dr hab. inż. Andrzej Kotecki
ul. Sopocka 23, 50-344 Wrocław, tel. 71 328 12 77
e-mail: wyd@up.wroc.pl

Nakład 100 + 16 egz. Ark. wyd. 6,4. Ark. druk. 5,75
Druk i oprawa: EXPOL, P. Rybiński, J. Dąbek, Spółka Jawna
ul. Brzeska 4, 87-800 Włocławek

SPIS TREŚCI

1. INTRODUCTION

Along with the development of human civilization, with the attempts to provide comfort and safety for inhabitants of various areas, and with the necessity to provide a sufficient amount of water for municipal, energetic and industrial purposes, emerged the idea of building dam reservoirs. Industrial development added to such reservoirs another function consisting in the storage of waste. The concept of constructing objects that perform such function has been controversial for quite a long time. Controversies arise from the influences of such reservoirs, starting from the changes in land development, landscape changes, forcing the relocation of inhabitants, destruction of natural ecosystems, hydrological transformations and, as a consequence – climate changes. The extent of threat that can be caused by such reservoirs is confirmed by the words of Mr Joseph Ellam, Director of Pennsylvania Department of Dam Safety: "There is no other structure constructed by humans, apart from nuclear power plants, that would have such potential to destroy the lives of so many people, as a dam" [in: Wita et al. 2007]. In spite of numerous objections related to the existence of reservoirs, in many cases they create the only opportunity for the development of various areas and industrial sectors, and their advantages outnumber the disadvantages.

Climate conditions and factors that are influenced by the test site belong to the physical variables of the geographical environment that shape life on Earth, influencing social organization and the functioning of societies in space and time and determining the limits of their activities. On a local scale, most of the changes in environmental components appear as a result of changes in land usage methods [Yoshino 1997].

The objective of the conducted tests is to study climate changes resulting from the introduction of a specific amount of water suspension in form of a reservoir to the landscape and the related transformations in natural land topography. Obtaining extensive knowledge about the distribution of temperature and humidity gradients and wind speed will create a basis for proper protection of valley slopes or elevations located in zones affected by strong winds, large temperature and air humidity amplitudes.

Our attention should be directed to the test object, whose main function is the storage of waste from the processing of metal ore and the recirculation of water for such processes. "Żelazny Most" is the biggest European tailing pond for the neutralization of mining waste. The annual mass of waste from the floatation of copper ore deposited here in the period 1992–2009 ranged from 21–29 million mg per year. In comparison, the total amount of industrial waste created on the territory of Lower Silesian Voivodship, where "Żelazny Most" is located, in 2000–2008 amounted, on the average, to 30 million mg per year (Report by the Voivodship Institute for Environmental Protection (WIOŚ) – The condition of Lower Silesian natural environment in 2008).

Although "Żelazny Most" has been in operation for over 30 years now, no studies have been conducted so far in order to evaluate the extent of modification of local climate conditions caused by this object. The aim of the analysis of climate conditions in the region affected by the object is to determine whether its presence causes changes in natural air temperature and humidity and in wind speed. It is possible to prepare a characteristic of the local climate of a given area and the evaluation of the transformations therein influenced by climate-shaping conditions basing on environmental monitoring [Obrębska-Starklowa et al. 2001]. Such studies have been conducted on the analysed area since 1996 and in the form presented in this study – since 2003.

The research query in Polish and world literature of the topic did not result in any publications discussing the issue of the influence of such objects on the local climate. However, there are numerous analyses of the influence of artificial reservoirs on the local climate. Basing on these, it could be assumed that the presence of such type of structure as is represented by "Żelazny Most" transforms natural thermal and humidity conditions, but mainly wind conditions.

2. OBJECTIVE AND SCOPE OF THE STUDY

The main objective of this study is the presentation of results of tests whose aim was to obtain deeper knowledge about the formation of selected properties of local climate taking into consideration the influence of a tailing pond (hereinafter referred to as TP) on local climate, by means of analysis of the modifications in the temperature, humidity and wind conditions. The selected test site is the area where the copper tailing pond "Żelazny Most" is located, in Rudna, in Lower Silesian Voivodship. The object is unique both from the scientific and technological point of view, as it is the largest deposit of liquid waste in Europe, and one of the largest in the world.

Pursuant to Art. 24 of the Mining Waste Act [Journal of Laws N°138. item 865], the manager of a tailing pond is obliged to manage the object in such a way that will prevent dust and gas emission. This requirement can be fulfilled only provided that the local climate conditions in the area of the object are well known. The characteristics of wind, humidity and temperature conditions provides a basis for the preparation of forecasts of meteorological conditions on the object and in the surrounding area, and eventually for taking the necessary steps preventing negative influence on the quality of atmospheric air. It should also be emphasized that changes in microclimate also influence the living conditions of local inhabitants and the attractiveness of the surrounding area for investors.

The scope of this study encompasses the analysis of literature, archived data, field tests and the analysis of results. The main objective of the literature search query for the purposes of this study is to describe the state of knowledge about local climate, microclimate and topoclimate. The presentation of these issues allows the reader to fully understand the title of this study. Another aim of the literature search query was to present the factors influencing the formation of the analysed climate components, i.e. air temperature and humidity and wind speed in the analysed area as well as in similar areas, and to present the main areas of focus of local climate research both in Poland and throughout the world. During the analysis of archived data the author attempted to find the results of meteorological data from the period preceding the construction of the object and from the beginning of its operation. Unfortunately, no measurements were taken in that period. The author's own field studies conducted for several years were aimed at the creation of a broad database that would enable to conduct the analyses presented in further chapters of this study.

Basing on the survey of literature and on the available information about the analysed object and climate factors, the following hypotheses were made:

Tailing pond "Żelazny Most" influences the local climate in the adjacent area.

The modifications of local climate caused by the influence of "Żelazny Most" can be described in form of changes in temperature, humidity and wind conditions.

3. CHARACTERISTICS OF THE TAILING POND "ŻELAZNY MOST"

The tailing pond "Żelazny Most" is a key element in the technological chain of copper production. At the same time, it is one of the major sources of changes in the natural environment in this part of Lower Silesia.

The object is the site of deposition of flotation tailings from Ore Enrichment Facilities (ZWR) from the mining areas: Polkowice, Lubin and Rudna. From the administrative point of view, "Żelazny Most" is located in Lower Silesian Voivodship, on the area of three communes (Fig. 1) [Czaban, Górski 2000]:

- Rudna – 9.18 km$^{2.}$ which represents 58% of the total area of the object,
- Polkowice – 5.23 km$^{2.}$ which represents 34% of the total area of the object,
- Grębocice – 1.26 km$^{2.}$ which represents 8% of the total area of the object.

The construction of the TP started in 1973 and it has been continuously exploited and extended since 1977. The central part of the object contains a water reservoir. As a result of the continuous process of waste storage and embankment formation, its main parameters are constantly changing. In 2009 the total area of "Żelazny Most" amounted to 1394 hectares, which was 16 hectares less than in 1999. During the years also the volume of deposited waste has been increasing. The damming curve shows that in 2009 it reached 445 million m^3 and that from 1999 it grew by 149.1 million m^3. "Żelazny Most" is an open elevated object. At the present moment, further extension and formation of the dams of the object is planned, to dam elevation of 195 m above sea level, and expanding the object by an additional southern part [Czaban et al. 2011].

The waste from Ore Enrichment Facilities, in form of ground rock, mine waters and substances used in the floatation process is discharged through a network of large-diameter main pipes and then through smaller pipelines directed to parts called sections, where alluviation takes place. Smallest particles of waste are discharged to the centre of the object by pipelines embedded on piers (embankments perpendicular to the dams). The waste is deposited in the storage area according to the main principle of the so called ring alluviation, where sandstone-type of waste is directed to the water slope of the dams, while waste of smaller granulation, silts and carbonates are directed to the centre of the object. As a result of the sedimentation of the alluviated waste, so-called beaches are created along the dams, and in the central part of the object emerges a reservoir of oversedimentary water which is then directed by tower intakes back to the flotation process.

3.1. FACTORS INFLUENCING THE CLIMATE IN THE TESTED AREA AND THE CHARACTERISTICS OF THE CLIMATE

The tailing pond "Żelazny Most" is located in the Lower Silesian Voivodship. Polish literature on climatology presents plenty of information about the climate conditions of Lower Silesia. However, no detailed characteristics of the area influenced by the waste deposit have been prepared so far, although they would have been very useful for the purposes of this study. The climate conditions in the area of the deposit are similar to standard climate conditions in this region of Poland.

The climate of Lower Silesia is shaped by processes of energy and water circulation and atmospheric circulation characteristic for moderate latitudes. The meridional extent of the voivodship's borders is quite small, which causes relatively small differences in the solar radiation energy intake. The mean annual total radiation in Wrocław is 3685 MJ/m^2 [Dubicka 1994].

The climate in the analysed area belongs to the group of moderate climates with transitional properties between marine and continental climate. The coexistence of marine and continental climate properties as well as the occasional inflow of arctic and tropical air leads to a quite high variability of weather types during the year. In 1948 Kosiba specified five main types of weather most common in this area:

- cyclonic weather of North Atlantic origin (the most common type), with inflow of humid masses of marine polar air from the Atlantic Ocean,
- anti-cyclonic warm weather in the summer, connected with the influence of the Azores anticyclone,
- cyclonic warm and humid weather of Mediterranean origin, causing high, intense flooding rainfalls in the Sudety mountains,
- anticyclonic cold weather, with the inflow of continental polar air masses,
- spring (April) weather – changeable, with the inflow or Arctic air masses.

As a result of analysis of the frequency of occurrence of various types of weather, Woś [1999] distinguished three climatic regions in the lowland part of Lower Silesia: Southern Greater Poland region, western Lower Silesian region and central Lower Silesian region.

Current changes of the climate in this part of Lower Silesia are characterized mainly by the occurrence of strong, irregular fluctuations and a growing tendency in air temperature. The growth of mean annual temperature in Wrocław in the 20th century reached +0.46°C/100 years [Dubicka, Pyka 2001]. A specific instance of the climate changes in the lowland part of the voivodship during the period 1971–2000 were recorded cases of absence of climatological winter.

The area of Lower Silesian voivodship is characterized by a high variability of thermal relations. The highest mean annual temperatures from the period 1971–2000 occurred in the Silesian-Lusatian Lowland and the Silesian Lowland (Legnica 8.8°C, Wrocław 8.7°C). These areas belong to the warmest regions in Poland [Paszyński, Niedźwiedź 1999]. With the elevation above sea level, mean annual temperature decreases on the average by 0.55°C/100 m.

The annual course of air temperature in Lower Silesia is typical for the climate of Polish lowlands, with a minimum in January and a maximum in July. In the lowland part of the Lower Silesian voivodship the longest thermal season is the summer, which lasts, on the average, for 96 days in Wrocław, and the shortest is winter (41 days) [Głowicki, Otop 2005].

The annual cycles of thermal phenomena sometimes differ from the one described above, which is an average from 30 years, and has a roughly sinusoidal form [Kożuchowski 2000]. The disturbances in the cycles of annual temperature course are connected with irregular influences of atmospheric circulation. Western cyclonic circulation causes periodical warming in winter and relatively cool seasons of the so-called European monsoon in July. Eastern circulation, in turn, has a cooling effect in winter, and in the warm part of year causes positive thermal anomalies, especially in July and in the early autumn period [Paszyński, Niedźwiedź 1999].

The wind conditions in Lower Silesia are shaped by the character of the general atmospheric circulation over Central Europe locally modified by terrain formation and varied roughness coefficient of ground cover.

The analysis of mean annual frequency of occurrence of different wind directions in the years 1971–2000 shows a domination of the Western direction on a major part of lowland regions of Lower Silesia (Legnica – 25.9%). Direction NW prevails only in Wrocław (21%), although also with a large share of W (18.3%) and SE (17.4%) directions [Głowicki, Otop 2005].

The velocity of wind in the lowland region of Lower Silesia is relatively low in comparison to other regions of Poland. The mean annual velocity from the period 1971–2000 falls within the range 2–3 m·s^{-1}·depending on the region. Locally increased velocity up to 3.5 m·s^{-1} is observed in the area of Legnica and Zgorzelec, as well as on isolated hills and in the peak part of Sudety. On Śnieżka wind speed reaches record values for Poland (12.7 m·s^{-1}).

The highest mean annual values of wind speed are noted in the winter months, usually in January (Zgorzelec 4.4 m·s^{-1}·Legnica 4.1 m·s^{-1}). The average velocity from the Western direction, most common in Legnica reaches 5.9 m·s^{-1} in January and 5.7 m·s^{-1} in December.

Strong wind, of a velocity exceeding or equal to 10 m·s^{-1} is noted with a mean annual frequency ranging from 1% in the eastern and northern parts of Lower Silesia and in mountainous basins, to 2% in Legnica and Kłodzko and 59% on Śnieżka. The share of very strong winds ($V > 15$ m·s^{-1}) on most of the territory of the voivodship is insignificant and usually does not exceed 0.1% of observations recorded on sites. The maximum values of the standard indicator of 10-minute wind speed in the lowland areas of Lower Silesia reach 18–20 m·s^{-1}· and momentary gusts, which are related to high air pressure gradients over Central Europe, exceed 30 m·s^{-1} [Głowicki, Otop 2005].

According to Schmuck [1960, 1961] the analysed area is located on the border of two climatic regions: the Oder region of Wrocław and Legnica and the Greater Poland region. On the other hand, according to Woś [1999], the studied area is located on the border of the southern Greater Poland region and the western Lower Silesian region. The most common type of weather throughout the year is moderately warm (132–138 days) and very warm (86–88 days). What differentiates the region from surrounding areas is the frequent occurrence of moderately warm, cloudy weather without rainfall (49–51 days). Significant frequency of occurrence of hoarfrost weather (73–78 days) and frosty weather (28–30 days) was noted. This is one of the warmest regions in Poland. The mean annual temperature is 8.4°C (warmest month – July, 18°C, coldest – January, -1.8°C).

Detailed characteristics of climatological conditions of the region, prepared basing on own tests and studies, have been presented in further sections of this study.

3.2. PHYSIOGRAPHIC CONDITIONS

The analysed area is located, according to the physiographic division of Poland, within the Central European Lowland Province and Central Poland Lowlands Sub-province. The TP is located in a morphological lowering of the south-eastern part of Wzgórza Dalkowskie Hills, which are, in the regional aspect, part of the Silesian Bank. The Wzgórza Dalkowskie Hills are an end moraine. The range of Wzgórza Polkowickie Hills is situated to the south from "Żelazny Most". To the north, the lowering where the object is located is bordered by lower ranges of Wzgórza Dalkowskie Hills (elevation ranging from 138 to 150 m above sea level). These hills separate the area of the object from the plain situated further north, with land elevations of approx. 80 m above sea level, which constitutes a part of the Barycko-Głogowska ice marginal valley [Kondracki 1965, 1969, 1977, 1998, Pernarowski 1970].

4. MAIN FACTORS INFLUENCING LOCAL CLIMATE

In literature on climatology topoclimate is usually considered as a synonym of local climate [Yoshino 1975]. In order to analyse these two notions more precisely, it is necessary to have a closer look at their etymology. The meanings are the same: the Greek word topos is an equivalent of the Latin locus. Both terms mean a place, understood not as a point, but rather as a small area or territory. Due to that, the words topoclimate and local climate can be used as synonyms.

The first one to use the term topoclimate was the American scientist Thornthwaite in 1953. In his "Introduction to arid zone climatology" [1958] he wrote: "The climate of a very small area can be referred to as topoclimate and studies of such climate – as topoclimatology". According to Thornthwaite, topoclimate is the climate of a place that can be described in topographic terms. German climatologist Geiger stated that the subject of topoclimatologic research are the "relations between terrain forms and local climates" [Geiger 1969]. According to Okołowicz, topoclimate is the climate of a place or object that can be described in topographic terms, corresponding to the lowest range in taxonomic classification and not existing independently, such as: slope of a valley, beach, the border of forest and the climate of objects constituting independent units: gravel pits, groves, city squares [Okołowicz 1969]. Among Polish authors, the works of Paszyński, who uses the exchange of energy between the atmosphere and the ground as the basis for topoclimatic charting, are often quoted. He claims that the existence of separate topoclimates is a result of heterogeneous influence of the active interface land-atmosphere on the processes occurring in the adjacent lower layer of the atmosphere [Paszyński et al. 1999].

Numerous authors consider the term topoclimate as synonymous with microclimate. Geiger [1969] defines microclimate as the climate of surface-adjacent, two-meter deep layer of air, where the vertical differentiation of temperature and humidity depends on the colour and physical composition of the soil, its thermal capacity, degree of moisture, characteristic properties of plant cover, albedo and roughness. All these properties of the soil, influencing the heat and moisture exchange, shape the vertical differentiation of the elements specified above in the surface-adjacent layer. Thornthwaite [1964] describes microclimatology as the science studying the heat exchange in the surface-adjacent layer and factors influencing such exchange. He claims that the individual vertical differentiation of temperature, humidity and wind speed in the ground-adjacent air layer results from the exchange of kinetic energy, heat and moisture between the surface of the soil and the atmosphere.

The climate system seen as a "collection of elements" contains, among others, atmosphere, hydrosphere, the outer layer of lithosphere including pedosphere and biosphere. The relations between them manifest themselves in form of streams of energy and substance, participating in the exchange between the elements of the system. Energy is also exchanged between the system and its environment [Kożuchowski 2006]. Bertalanffy [1984] defines a system as "a set of elements, standing in interrelations with each other and with their environment". Thus, it proves that the notion of system can well be used in order to explain the genesis and structure of atmospheric states, i.e. of the climate. This approach consists in the application of physical methods to study, model and forecast the climate.

The energy supply to the system is highly dynamic. We observe cyclical, daily and seasonal fluctuations as well as non-periodical disturbances. The main sources of irregular fluctuations are air movements of a turbulent nature. They are not only characteristic for the wind and convection, but also for heat distribution. A significant role in the heat exchange is played by the latent heat of vaporization. The atmospheric distribution of such heat depends on the processes of evaporation and condensation, which are often influenced by random events. A good example may be the dust pollution of the atmosphere, which contributes to the condensation of water vapour in the air and the release of latent heat [Kożuchowski 2006].

Climate is defined as typical atmospheric conditions, obtained from long-term observations, characteristic for the given place, depending on geographical conditions [Chromow 1969]. The term "geographical conditions" is broader than just the location, i.e. the latitude, longitude and elevation above sea level, but also refers to the type of ground, orography, soil cover and other factors.

According to Kożuchowski [2006], factors shaping local climate are connected with the influence of the lower parts of atmosphere on the higher layers, of a very limited vertical and horizontal extent. They depend mainly on the land formation, type of soil directly under the atmosphere and its coverage. Their influence is always subordinate to factors creating the climate on macro scale.

The mechanisms of operation of local and macro geographic factors are nearly identical. These are physical processes (heat and moisture circulation, air circulation). The property that differentiates them is the spatial scale, which, for local elements, limits the extent of influence to the ground-adjacent borderline layer. In the horizontal dimension they affect the state of the atmosphere directly above a specific type of ground, and their effects are rarely extended beyond the nearest surroundings.

The mechanism of heat circulation functions as follows: the stream of solar radiation moves through the atmosphere, where it is partly absorbed and transformed into thermal energy, and partly dispersed. Another part is reflected from the clouds. The amount of radiation that reaches ground surface, is reflected, and, in a large part, absorbed and used to heat the top layer of the soil and of water reservoirs. Ground surface and atmosphere are also sources of invisible infrared radiation, which is also used for the heating of air and ground. Apart from heat exchange, also the phenomenon of heat conductivity is observed along the path of radiation. The process of mixing of air also plays a significant role in the heat exchange. A significant part of the heat that reaches the ground is used for water evaporation (latent vaporization heat). Later, during the process of water vapour condensation, the latent heat is released and used to heat the air.

Apart from the heat exchange between the atmosphere and the ground there is a continuous circulation of water. Water evaporates from the surface of reservoirs, from moist soil and transpires from plants to the atmosphere. This process uses up large amount of heat from the soil and from superficial layers of reservoirs. Water vapour is also subject to reverse transformations: condensation and concentration which leads to the creation of clouds and fog. During the condensation process, latent heat is released in the atmosphere. The final stage is precipitation, a phenomenon that balances the evaporation process and brings the water back to the ground.

The uneven distribution of heat in the atmosphere causes differences in the distribution of air pressure, which in turn leads to the occurrence of air movements. It is assumed that they are shaped by the influence of Earth's rotation around its axis. On the other hand, in the lower layers of atmosphere air movements are influenced by the phenomenon of friction. Air movement in relation to the surface of the ground is called wind, and the whole system of air currents – general atmospheric circulation. The general circulation influences significant large-scale weather changes (changes in temperature, humidity, cloud coverage, etc.) Also, local air circulation is observed, which affects smaller areas.

The properties of the active surface in terms of energy exchange are shaped by the following factors:

- geometry of the surface,
- albedo of the surface,
- transparency of the atmosphere,
- thermal properties of the ground,
- moisture–related properties of the ground,
- aerodynamic properties of the ground.

The formation of terrain allows us to distinguish areas of different exposure. At our latitudes, it is important to distinguish between southern and northern exposure, considering the amount of active energy reaching the surface. Regardless of the exposure, the climate is influenced by the inclination of slopes, mainly due to local advection of cold air. When considering the albedo of the active surface, it is understood as the value determining the capacity to absorb solar radiation. Due to possible decrease in atmospheric transparency, causing the reduction of direct solar radiation, areas with high dust or smoke pollution should be distinguished. The ground may be characterized by varied degrees of thermal conductivity and thermal capacity. These factors are highly influenced by the type of soil and the moisture content. The moisture content on the interface earth-atmosphere is very important for the division of energy into a flux of sensible heat (used for heating the air) and latent heat (used for evaporation). It is necessary to consider surfaces that constantly remain wet: reservoirs, swamps and areas covered by thick plant cover with a continuous water supply from the soil, as well as arid surfaces: rocks, areas transformed by human activity – dense urban and industrial development – where rainfall is quickly discharged through sewage systems. The roughness of the ground is an important factor shaping the turbulent exchange of sensible and latent heat. It also decides about the split of energy between heat conducted inside the ground and heat migrating to the atmosphere [Kożuchowski 2006, Paszyński et al. 1999]. The properties listed above have been considered during the analysis of the influence of the TP on the local climate, as presented in the following chapters.

The climate conditions of a given place depend mainly on the amount of energy reaching the ground and on the way in which it is used for various physical processes. Due to that, it is important to know the energy balance of the borderline surface and its structure. The term structure is understood as the interrelations between individual elements of the balance [Paszyński et al. 1999]. The energy exchange on the interface earth-atmosphere is presented in a quantitative form of the energy balance equation. The most simplified form of this equation is presented below:

$$Q^* \pm H \pm E \pm G = 0 \qquad (1)$$

where: Q* is the radiation balance (W/m^2), H – turbulent flux of sensible heat (W/m^2), E – flux of latent heat connected with evaporation and condensation (W/m^2) and G – the stream of heat conducted within the ground (W/m^2). Each of the listed properties is determined by a sign defining the direction of the given flux: from the atmosphere to the interface surface or the other way round. Individual elements of this equation correspond to the main forms of energy transport: radiation, rising and conductivity. The thermal radiation balance equation is formulated as follows:

$$Q^* = K\downarrow - K\uparrow + L\downarrow - L\uparrow \qquad (2)$$

where: $K\downarrow$ is the total solar radiation (MJ/m^2), $K\uparrow$ reflected solar radiation (MJ/m^2), $L\downarrow$ radiation returned from atmosphere (MJ/m^2), $L\uparrow$ heat radiation of the ground (MJ/m^2). The structure of radiation balance, thermal radiation balance and their variability are influenced by local factors, such as the type of land usage [Paszyński 2001].

Radiation is the emission of energy in form of electromagnetic waves from any body of a temperature exceeding absolute zero. Conductivity takes place when there is a difference in temperature in a given medium or in adjacent media. Conductivity of energy dominates in solids, e.g. in soil, and, to a smaller extent, in liquids. The phenomenon of rising in gaseous or liquid media occurs as a result of the movement of the medium – as transport of energy with mass (convection – vertical movement, advection – horizontal movement). Rising plays a vital role in the transportation of water vapour in the atmosphere and the connected transport of latent vaporization heat. This heat is released and transformed into sensible heat during condensation, e.g. during the formation of dew. A similar and converse transformation takes place during the freezing of water, melting of snow or ice [Paszyński et al. 1999]. The structure of the heat balance of the active surface is influenced by several main factors [Kędziora 2008]:

- balance of radiation (depending on: latitude, season, time of day, cloud coverage, albedo of the surface, water vapour content in the air, temperature of the active surface and temperature of atmosphere),
- flux of latent heat (depending on: radiation balance, plant coverage, moisture content of the ground, atmospheric humidity, vertical gradient of water vapour concentration in the air, wind speed, status of atmospheric thermodynamic balance),
- flux of sensible heat (depending on: radiation balance, type of ground, vertical gradient of air temperature, moisture content of the ground, wind speed, status of atmospheric thermodynamic balance),
- flux of soil heat (depending on: vertical gradient of temperature in the soil, moisture content of the soil, porosity of the soil).

For the purpose of topoclimatological studies it is assumed that standard conditions are represented by flat terrain, with uncovered horizon, overgrown with low grass. This is a topoclimate of reference, to which the values noted in other types of environments are compared [Paszyński et al. 1999].

4.1. WATER AS ONE OF THE FACTORS SHAPING THE CLIMATE

Water is a factor that shapes the climate in two aspects:

- directly – as a type of ground, e.g. water reservoir,
- indirectly – as moisture in the soil, modifying the soil's thermal properties and determining the value of evaporation from the ground.

Moreover, water in form of a snow or ice cover is also an important element influencing the climate.

The influence of water results from its thermal properties, different from those of solid ground and from its ability to evaporate. Thermal capacity of water is approx. 4.18 MJ/m^{3}°K, and the coefficient of thermal conductivity approx. 0.6 W/m°K, whereas the thermal capacity of various rocks and soils falls within the range 1–3 MJ/m^{3}°K, and the conductivity coefficient – 1–3 W/m°K. This means that less heat is required to raise the temperature of 1 m^{2} of solid ground by 1°K than to raise the temperature of water. As a result, if the same amount of solar radiation reaches the surface of water and the surface of soil, the soil will be heated to higher temperature. Weaker heating of water results not only from its thermal properties, but also from the fact that part of the absorbed radiation energy is used for evaporation, and only later the remaining part is transported deeper as a result of mixing of water [Kossowska-Cezak, Bajkiewicz-Grabowska 2008].

Temperature differences between water and land are visible both in the daily and the annual cycle. In summer land heats faster and to higher temperatures, in winter it cools faster and has a lower temperature. As a result, the presence of water reservoirs influences the climate conditions of its environment on a spatial scale (in particular the temperature and humidity conditions).

A good example illustrating this phenomenon can be the difference in temperature between the surface of land (beach) and of the sea. Sand absorbs different amounts of energy, depending on its colour. As the specific heat of sand is low, its temperature grows quickly during heating. Sand also has low heat conductivity, so that the radiation is absorbed by only a thin layer. As a result, during the day the temperature of sand surface grows quickly. At night, when solar radiation stops, the land starts to lose heat through emission. The temperature of the surface of the beach is subject to large daily fluctuations. On the other hand, water absorbs a large part of solar radiation energy. Due to high value of specific heat, its temperature grows slowly. Part of the radiation reaches the depth of several meters, and mixing of water leads to the heating of a significantly thick layer. Moreover, some part of the energy is transformed into latent heat and used in the evaporation process. As a result, the temperature of sea surface does not grow as fast as that of land surface, and the differences in sea surface temperature during the day and in the night are small [Retallack 1991].

The differences in shaping of the thermal conditions around a water reservoir are related to the physical properties of water, its ability to absorb and emit heat energy. The subject of the influence of water reservoirs on air temperature has been widely discussed in literature.

Studies on this subject were conducted by Lewińska [1966, 1969, 1974]. During tests in Czorsztyn and Nidzica, she observed a growth in average air temperature by 0.3°C in a year. Analysis of the daily cycle showed that mean annual temperature measured at 7 am and 9 pm had grown, but temperature measured at 1 pm had fallen. She also noted a decrease in the annual average maximum temperature (by 0.9°C), and a growth of the annual average minimum temperature (by 3.3°C). Lewińska also noted that the annual amplitudes of temperature were flattened by 2.5°C throughout the year. Similar results were obtained by Marzec [1971]. He observed a growth in annual average temperatures, in particular during the period August-December. In the daily course, he noted lowered temperatures between 10–12 hours in the zone adjacent to the reservoir, and during the remaining part of day he proved that the air temperatures grew. He also observed a flattening of the annual amplitudes. According to this author, the influence of a reservoir on air temperature is more strongly manifested in the second half of year. The studies of Kostrakiewicz [1984] on Carpathian reservoirs confirm the above conclusions. Lorenc and Suwalska [1991] observed a growth in average annual temperatures by 0.2°C and in annual average minimum temperatures by 0.6°C in the surroundings of Sulejowski Reservoir and a lowering of annual average maximum temperatures by 1.1°C. The observations in Gaik-Brzezowa conducted by the team led by Obrębska-Starklowa [Obrębska-Starklowa 1995, Obrębska-Starkel 2002, Bokwa 2008, Matuszyk 2008] showed mainly that the spatial differentiation of air temperature is influenced both by terrain formation and land usage, although their role and significance vary depending on the season and time of measurement. Most recent analyses by Małecki [2009] show a growth in minimum temperatures in winter and a fall in maximum temperatures in summer near the Pokrzywnica reservoir.

Research conducted so far has not explained the influence of water reservoirs on humidity conditions in adjacent areas yet. The only proven finding is the fact that the spatial differentiation of air humidity in areas adjacent to reservoirs is influenced by the usage and formation of the surrounding land. Studies on the influence of water reservoirs on air humidity have been conducted since the 1950s. Sapożnikowa [1953] claimed that the proximity of water reservoirs leads to an increase in relative humidity. Kaczorowska [1953] noticed that inland reservoirs cannot provide such amounts of water vapour that would significantly influence the humidity of higher air layers, and thus higher humidity should be expected in the proximity of the reservoir than in areas beyond its zone of influence. Zych and Boniecka-Żółcik [1962] proved, basing on climatological research at the Goczałkowice Lake that water reservoirs increase air humidity, at the same time emphasizing that in the studied area such situation may result from a large amount of atmospheric calms causing a stagnation of humid air. Okołowicz and Olszewski [1969] conducted research on a natural reservoir, namely the lake Śniardwy. Their findings proved that a large water reservoir causes a certain increase in absolute humidity in the adjacent area. The reach of such influence is relatively small and rarely noticeable at stations located 10 km from the reservoir. A significant influence can be observed only on stations located near the banks, provided that they are suitably located in relation to dominant winds. On the other hand, Morawska [1969] noted a decrease in mean annual air humidity by 0.3% in the proximity of water reservoir, and an increase by 4.7% at 13 hours. The works of Lewińska [1966, 1974] are particularly noteworthy. She claimed that a water reservoir does not cause an increase in air humidity, but conversely, a decrease. She estimated that this was connected with lower cloud coverage and higher wind speed over the reservoir. However, she added that sometimes, over lowland reservoirs, an increase in humidity may be expected, which is related to the rise of groundwater surface. Marzec [1971] in his studies on the Rożnowski Reservoir proved a decrease in the relative air humidity in the adjacent area. He noted that this was caused by increased wind speed around the reservoir, which makes it impossible to retain water vapour. Studies conducted by Lorenc and Suwalska [1991] on the Sulejowski Reservoir showed a slight increase in mean relative humidity by 3% per annum, in the areas adjacent to the reservoir. The authors pointed out that this tendency is particularly visible in the summer months (even up to 6%), and in the afternoon hours throughout the year. The observations of Obrębska-Starklowa [1995, 2002], Obrębska--Starklowa, Grzyborowska [1997], Bokwa [2008], Matuszyk [2008] taken in Gaik-Brzezowa proved that a water reservoir does not have a significant influence on this climate factor. They proved that land usage and terrain formation influence the changes in relative humidity and in the resilience of water vapour in the area of the reservoir but that their role and significance vary depending on the season.

Wind plays a significant role in the formation of climate in the area of water reservoirs and it participates in the heat and water vapour transportation. The movement of air in the layer adjacent to soil is subject to significant modifications depending on the type and formation of ground. Studies on wind speed and its changes influenced by the proximity of water reservoirs show that water reservoirs influence the velocity of wind and limit the number of atmospheric calms, although at the same time these changes depend on the initial anemometric conditions in the given region.

Following the study conducted in Kotlina Orawsko-Nowotarska, Wierczek [1968], was the only one to conclude that the construction of a reservoir would not modify wind speed. Relatively broad descriptions of wind conditions in the area of reservoirs are presented by Marzec [1971], Lewińska [1974], Krystek, Lorenc [1974]. The authors believe that wind speed increases within the zone of influence of the reservoir. Studies conducted on Rożnowski Reservoir have shown the influence on the daily course of this factor, in particular the smaller amount of atmospheric calms in the afternoon hours is worth noting. The strongest winds were observed in summer/autumn and wind speed grew by 3–5 m·s^{-1}. Lewińska, in her study on Solina, noted that the amount of calms decreased by as much as 20% and wind speed ranging from 2 m·s^{-1} increased to 17%. Higher frequency of occurrence of winds of velocity ranging from 5–10 and 10–20 m·s^{-1} was proven by the studies conducted on the reservoir in Włocławek. At the same time the amount of calms and weak winds decreased by 17%. More recent research by Lorenc and Suwalska [1991] and Małecki [2009] confirm earlier findings. On Sulejowski Reservoir a decrease in the frequency of calms and winds of velocity ranging from 0–2 m·s^{-1} was noted throughout the year, whereas the frequency of winds of velocity exceeding 5 m·s^{-1} increased by 5.3%. Małecki noted on the Pokrzywnica reservoir, an increase in wind speed by up to 10.7%.

The studies cited above present various degrees of explanation and description of modifications of natural climate conditions influenced by the existence of water reservoirs. However, it seems suitable to import some of the research methods for the purposes of the evaluation of the influence of the pond on the local climate near "Żelazny Most". One should also consider the similarity between the described objects and the tailing pond, which is a vast reservoir of liquid and semi-liquid waste.

4.2. RECENT STUDIES ON TOPOCLIMATE IN POLAND

At the moment there are several research centres that focus on the studies of broadly understood topoclimate.

One of these is the Institute of Geography and Spatial Organization of the Polish Academy of Sciences. The main areas of focus of this institution are studies on topoclimate, often extended by the evaluation of bioclimate, in several aspects: studies on climate of agricultural areas, urban-rural areas, health resort areas [Błażejczyk 2001, Błażejczyk 2002, Kozłowska-

-Szczęsna, Błażejczyk 2002, Kuchcik 2003, Błażejczyk, Kuchcik 2003, Kuchcik 2009] and issues related to topoclimate charting and the structure of heat balance of the interface earth--atmosphere, basing on fundamental studies by Paszyński [1972, 1980, 1989, 1991, 1995, 1999, 2001, 2004].

Another important Polish centre of research on local climate is the Institute of Geography and Spatial Organization of the Jagiellonian University in Kraków. The main area of focus of the scientists at this Institute is the climatological differentiation of the Carpathian Mountains. The test station in Gaik-Brzezowa is likely to have the longest series of comparative measurements of air and soil temperature for grassland and soil devoid of plants. Another important subject of research is the differentiation in the topoclimate conditions and the changes in the local climate of Pogórze Wielickie, in the region of Dobczycki Reservoir. The result of long-term studies on the climate shaping factors in the area adjacent to the reservoir is the evaluation of their hierarchy (descending order): the influence of terrain formation, influence of the reservoir, influence of the plant covers [Obrębska-Starkel et al. 2005]. This doctoral thesis takes into account particularly the publications by Obrębska-Starklowa [1984, 1995, 2002] Bokwa [2008, 2008] and Matuszyk [2008].

Broad studies on local climate are conducted by the Institute of Geography of the Mikołaj Kopernik University in Toruń. However, the institute focuses mainly on the characteristics of topoclimates and analysis of climate changes in the Norwegian Arctic, and to a lesser extent on Poland. These studies constituted the basis for the development of methodology of analyses by the author of this dissertation [Kejna, Marszewski 2007, Araźny 2008, Przybylak, Kejna 2008, Araźny, Migała 2009, Kejna, Uscka-Kowalkowska 2009, Uscka-Kowalkowska, Kejna 2009].

It is also worth to consider the publications from other research centres focusing with issues related to local climate. One should cite here the works by Korzeniewski and Marosz [2003] from the University of Gdansk, Durło [2005] from the Agricultural University in Krakow and Sobik, Miszuk [2005] from the University of Wrocław, on the changes in temperature, wind speed and direction in different terrain formations, Rozbicki and Golaszewski [2003], Rozbicki, Gołaszewski and Łykowski [2005] from the Warsaw University of Life Sciences, and Szymanowski [2004] from the University of Wrocław, on the transformations in local climate in cities.

4.3. RECENT STUDIES ON TOPOCLIMATE THROUGHOUT THE WORLD

Large projects encompassing the studies on the changeability of climate conditions in local scale are conducted at the Ontago University in New Zealand. The works of B.B. Fitzharris are particularly noteworthy. In his research the author focuses mainly on the characteristics of mountainous climates [1977, 1977, 1987]. In 1989 the author also conducted a survey of the studies on topoclimate-related subjects from 1898 to 1988. This survey shows that the subject of local climate was mainly connected with farming crops, and the changeability of parameters and climate processes in this area. In the 1990s, in New Zealand and Australia the Topoclimate South project was launched, whose aim was to analyse local climate conditions, in particular air temperatures, and then to apply the obtained results for agricultural purposes.

Another research centre focusing on topoclimate is the University of Gothenburg. Its main areas of focus are: the influence of car transportation on climate, urban climate, interactions between global and local climate, climate of wetlands [Andersson et al. 2007, Chen et al. 2007, Graham et al. 2007, Holmer et al. 2007, Linderholm et al. 2008, Eliasson 1996, Eliasson et al. 2006, Bogren et al. 2000, Upmanis 1999, Lindqvist 1992].

The Old Dominion University in Norfolk has also issued a large number of publications on the subject. These works concern, in particular, topoclimate studies related to the geomorphology of land, often also considering the topic of application of modern satellite techniques and GIS [Allen 1998, Walsh et al. 1993].

The research query in world literature shows that authors of works on topoclimate have already widely analysed the aforementioned issue of influence of roads on some meteorological parameters. Publications on the topic include the works of Bärring, Mattson, Lindqvist [1985], Bogren [1991], Bogren, Gustavsson [1991], Bogren et al. [2000], Elliasson [1996], Gustavsson [1990], Thornes, Shao [1991].

The works often deal with the topic of the influence of development and urban areas on local climate. Such studies have been conducted, among others, by: Goldreich [1992], Kuttler et al. [1996], Myrup et al. [1993], Unger et al. [2001].

The research query in world literature did not result in any findings related to works on the influence of tailing ponds and other industrial waste neutralization objects on local climate and its elements. Single works were found, concerning the transformations caused by water reservoirs [Rastorguev, Roshchina 1987, Zhierkevich 1992, Huntley, Baxter 1998, Miller, Jiming 2005, Hossain, Jeyachandran 2009].

In conclusion, it should be stated that topoclimatic research is a domain of science that is continually developing, although the basis for it was created as early as in the 1950s.

5. RESEARCH MATERIAL

The programme of the study takes into account those elements of climate that enable, in the course of further research, to determine and evaluate the changes in local climate.

The research material used for the purposes of this study consisted of the results of meteorological measurements taken in the Hydrotechnological Plant in Rudna, encompassing the tailing pond "Żelazny Most" as well as the measurements from the climatological station of the Institute of Meteorology and Water Management in Polkowice.

All measurements were taken with use of automatic Maws 101 stations manufactured by Vaisala (measurement of air temperature and humidity at 2 meters above ground level, wind speed at 10 meters above ground level). In order to minimize the differentiation and influences of other factors than those described in the study, meteorological stations were installed on specially separated plots, so called meteorological gardens. The application of automated meteorological stations facilitated the collection, gathering, storing and processing of meteorological data. The advantage of the use of such stations is the accuracy of obtained data and the frequency of the collection thereof. The issues related to the use of automated stations for measurement has been studied, among others, by Feleksy-Bielak et al. [2000], Rojek, Rojek [2000], Rojek et al. [2001], Bac, Żyromski [2006], Lorenc [2006], Kajewska and Rojek [2009].

The study focuses on three elements determining local climate: wind speed, air humidity and temperature, as they belong to the main climate factors, and at the same time they are relatively easy to measure.

The analyses use the temporary values from the period 2003–2009 from the measurement stations "Tarnówek", "Zapora", "Kalinówka", supplemented by average hourly values from "Polkowice" (2003–2005) and Rudna (2003–2009) as well as the values of measurements from the main observation periods 6 UTC, 12 UTC, 18 UTC (2006–2008) from "Polkowice". Data were recorded in digital form. The location of meteorological stations is presented in Figure 1. A short characteristics is presented in Table 1 and shown in Photographs 1 and 2.

Although the correct operation of stations was inspected from time to time during the measurement period, some problems were encountered. The main issue were periodical losses of data, caused by power supply failures. In 2006 also a system failure occurred in the Polkowice station, which made it impossible to take measurements throughout the day.

It should be emphasized that the results of meteorological measurements are valid only provided that the measurements are taken basing on the fundamental meteorological principle of comparability [Rojek, Żyromski 2004]. The requirement is fulfilled when the following main conditions are met:

- comparability of measurement sites,
- comparability of time.

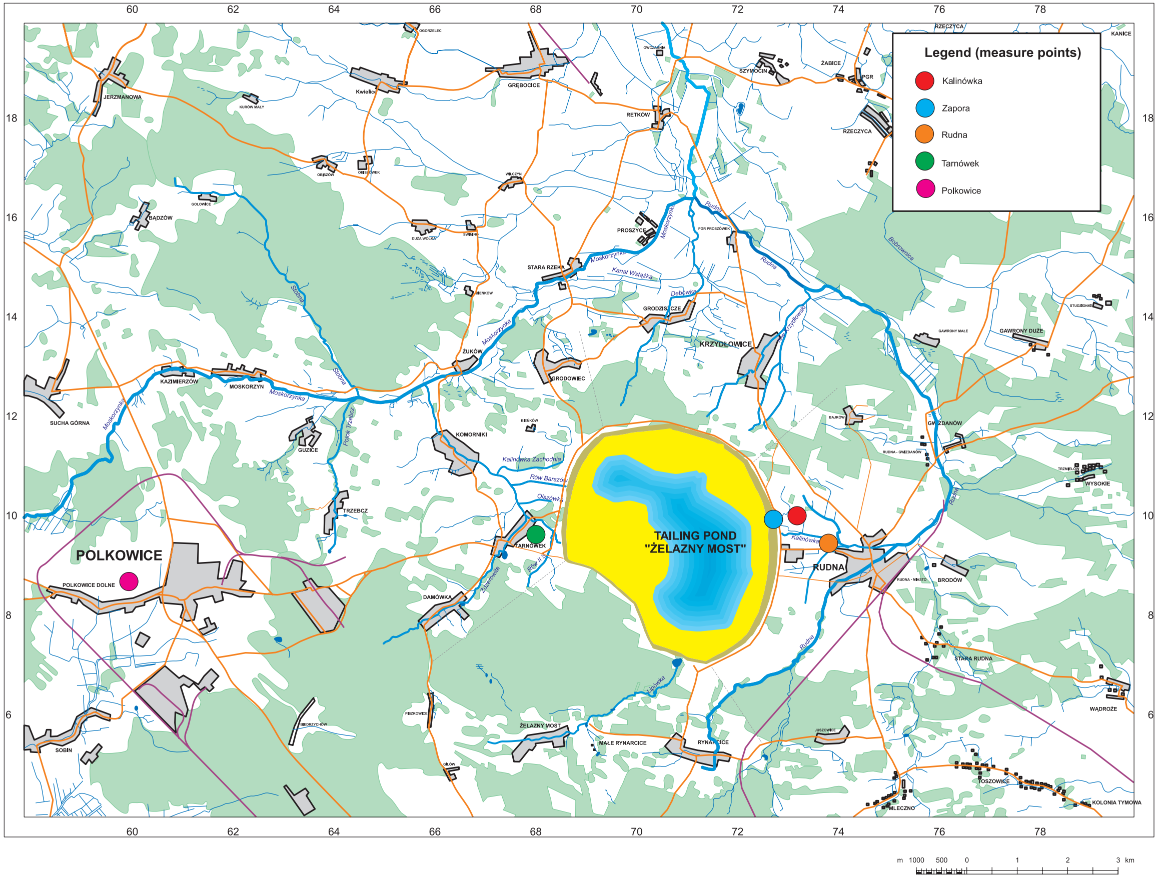


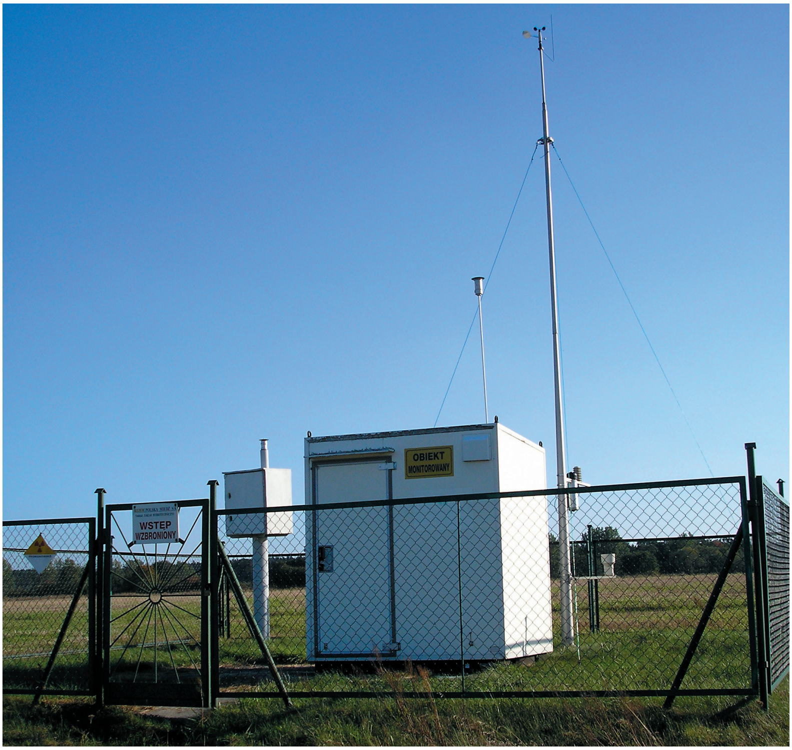
Fig. 1. Location of the measurement stations "Polkowice", "Tarnówek", "Zapora", "Kalinówka", "Rudna" (author: St. Czaban)
Rys. 1. Lokalizacja stacji pomiarowych "Polkowice", "Tarnówek", "Zapora", "Kalinówka", "Rudna" (aut. St. Czaban)

Table 1
Tabela 1

Characteristics of the measurement sites
Charakterystyka punktów pomiarowych

Station – Stacja	Location and type of ground coverage Położenie stacji i rodzaj pokrycia terenu
IMGW "Polkowice"	51°30‘ N 16° 2‘ E, standard conditions, no influence of TP, distance from "Żelazny Most" approx. 10 km in the W direction 51°30’ N 16° 2’ E, warunki standardowe, brak wpływu OUOW, odległość od "Żelaznego Mostu" około 10 km w kierunku W
"Tarnówek"	51°30‘ N 16° 9‘ E, approx. 60 m from the base of the dam, in the W direction, ground coverage – grass, single bushes 51°30’ N 16° 9’ E, około 60 m od podstawy zapory, w kierunku W, pokrycie terenu – trawa, pojedyncze krzewy
"Zapora"	51°30‘ N 16°14‘ E, located on the E crown of the TP, elevation 60 m from the base of the dam, 200 m from the reservoir 51°30’ N 16°14’ E, położenie na E koronie OUOW, na wysokości 60 m od podstawy zapory, 200 m od akwenu
"Kalinówka"	51°30‘ N 16°14‘ E, approx. 50 m from the base of the dam, in the E direction, ground coverage – grass, several dozen meters away from the utility buildings of the Hydrological Plant in Rudna 51°30’ N 16°14’ E, około 50 m od podstawy zapory, w kierunku E, pokrycie terenu – trawa, w odległości kilkudziesięciu metrów budynki gospodarcze ZH w Rudnej
"Rudna"	51°30‘ N 16°15‘ E, approx. 900 m from the base of the dam, in the E direction, ground coverage – grass, single trees and bushes, approx. 150 m from the buildings of Rudna village 51°30’ N 16°15’ E, około 900 m od podstawy zapory, w kierunku E, pokrycie terenu – trawa, pojedyncze drzewa, krzewy, w odległości około 150 m zabudowania miejscowości Rudna

The principle of comparability of measurement site for the discussed tests in locations "Tarnówek", "Kalinówka" and "Rudna" is met, as the measurement stations were located in meteorological gardens. One exception is the "Zapora", where it was impossible to meet these conditions. All gardens were located in open areas, away from buildings, trees, open water reservoirs, i.e. anything that could hinder the air exchange and directly affect measurement results. Within 30 m from the garden there are no structures, trees, bushes, or artificially watered crops. In the case of stations "Tarnówek", "Kalinówka" and "Rudna" there are only small, single objects located further that 30 m away from the gardens, such as detached houses or trees, and 100 m from the gardens there are low-density developed areas and small groups of trees, although they do not influence the measurement results. Thus, the only object affecting natural meteorological conditions is "Żelazny Most". The described location of test sites is compliant with the standards for the measurement of meteorological factors. The area of the garden is shaped in form of a 15 x 15 m square, with sides along the South-North and East-West lines. The area of the garden is levelled, without holes or hills, overgrown with grass. The devices for the installation of measurement equipment are painted white in order to minimize heating during hot periods. The whole area is enclosed with a net fence approx. 1.5 m high, which does not interfere with air flow. From spring to autumn the grass is regularly mowed in order to maintain consistent measurement conditions. In winter the snow remains in natural state until it melts.



a) Measurement station "Tarnówek"
Stacja pomiarowa "Tarnówek"

b) Measurement station "Zapora"
Stacja pomiarowa "Zapora"

c) Measurement station "Kalinówka"
Stacja pomiarowa "Kalinówka"

d) Measurement station "Rudna"
Stacja pomiarowa "Rudna"

Phot. 1. Field measurement stations – meteorological gardens (photo: J. Zapart)
Fot. 1. Terenowe stacje pomiarowe – ogródki meteorologiczne (fot. J. Zapart)

a) Surroundings of the station "Tarnówek" (TP visible in the background)
Otoczenie stacji "Tarnówek" (w tle widok na OUOW)

b) Surroundings of the station "Zapora" (in the background surface of TP)
Otoczenie stacji "Zapora" (w tle powierzchnia OUOW)

c) Surroundings of the station "Kalinówka" (TP visible in the background)
Otoczenie stacji "Kalinówka" (w tle widok na OUOW)

d) Surroundings of the station "Rudna" (buildings of the village Rudna visible in the background)
Otoczenie stacji "Rudna" (w tle widok na zabudowania miejscowości Rudna)

Phot. 2. Surroundings of the field measurement stations (photo: J. Zapart)
Fot. 2. Otoczenie terenowych stacji pomiarowych (fot. J. Zapart)

Current standards of the Institute of Meteorology and Water Management require taking 24 measurements per day, at full hours from 0:00 to 23:00. The hours of meteorological observations both in Poland and throughout the world, are recorded in UTC (Universal Time Coordinated) time. Additionally, international main hours of meteorological measurements are specified. These are 0, 6, 12 and 18 hours UTC, which corresponds, respectively, to the following official hours in Poland:

- during Daylight Savings Time (DST, summer) 2, 8, 14 and 20.
- during CET period (winter) 1, 7, 13 and 19.

The standardization of measurements allows the exchange of information (observations and measurements) between stations in Poland and throughout the world. The parameters discussed in the present study are measured with the respective accuracy:
air temperature – 0.1°C, relative air humidity – 1%, wind speed – 1 $m \cdot s^{-1}$ [www.imgw.pl].

The currently adopted reference period of climate studies is 30 years. Now the period 1971–2000 is used as reference period. The methodology of climate studies is based mainly on mean daily values for the purpose of analysis of air humidity and temperature. Until the year 1996, mean daily values of temperature and relative air humidity were calculated, pursuant to the Instruction for meteorological stations [Janiszewski 1988], basing on the measurements taken at 0, 6, 12, 18 hours UTC. After that year, new standards were introduced, so that currently mean daily temperature is calculated basing on the following formula:

$$T = \frac{t_{min} + t_{max} + t_{06} + t_{18}}{4} \tag{3}$$

where t_{min} is the minimum temperature noted throughout the day, t_6 – air temperature measured at 6 hours UTC, t_{18} – air temperature measured at 18 hours UTC,
whereas relative air humidity is calculated as follows:

$$W = \frac{2 \cdot t_{06} + t_{12} + t_{18}}{4} \tag{4}$$

where t_6 is the relative air humidity measured at 6 hours UTC, t_{12} – relative air humidity measured at 12 hours UTC, t_{18} – relative air humidity measured at 18 hours UTC.

In this study the standard methodology of the Institute of Meteorology and Water Management was not applied. Short measurement series in the area of "Żelazny Most" make it impossible to compare results with the values from the reference period specified above. Whenever values from a multi-annual period are mentioned, they refer to values from the period 2003–2008. As the most homogenous material is obtained from daily measurements at the main measurement hours, the author focused on detailed daily characteristics. Due to the fact that the measurements were taken with higher accuracy than suggested in the guidelines of the Institute of Meteorology and Water Management, in the case of wind speed it was decided to perform the analysis with an accuracy of 0.1 $m \cdot s^{-1}$. The changes of the analysed elements in time were characterized according to Universal Time Coordinated (UTC).

In order to meet the objectives of this study it was required to create a new methodology and to apply certain descriptive and statistical elements. The most important elements are considered the analysis of mean monthly and hourly values, daily course, frequency distribution, as well as the analysis of differences and testing statistical hypotheses (difference significance tests).

Small gaps in the obtained collection of data were filled by means of interpolation basing on adjacent points. In the case of larger gaps, e.g. from one of the stations, corresponding records from the remaining stations were removed.

6. ANALYSIS OF THE INFLUENCE OF THE TAILING POND "ŻELAZNY MOST" ON THE LOCAL CLIMATE BASING ON THE DIFFERENCES IN HUMIDITY, THERMAL AND WIND CONDITIONS

6.1. CHARACTERISTICS OF AIR HUMIDITY

Measurements of air humidity taken in the years 2003–2008 enabled the analysis of mean air humidity at 6, 12, 18 hours UTC from that period. It was noticed that the mean monthly air humidity varied for each station, depending on the hour of measurement. All discussed stations were characterized by highest mean monthly humidity in the morning hours. The lowest air humidity at that time was recorded at the "Dam" station. At noon, the air humidity at the stations decreases, while in the evening a slight increase is observed on all measurement sites. Such tendency manifests itself particularly at the "Polkowice" and "Zapora" stations. Basing on the mean monthly values from the analysed period, the highest air humidity occurs in winter (measurements at 12 and 18 hours UTC) and autumn (measurement at 6 hours UTC). Maximum values are observed in December and January at noon and in the evening, whereas for morning measurements the maximum occurs in October for stations "Polkowice", "Tarnówek", "Kalinówka" and "Rudna" (Fig. 2). The above findings are confirmed by the analysis of air humidity in individual years at the said hours.

The evaluation of influence of "Żelazny Most" on the mean monthly air humidity in the analysed period was based on the differences between the values noted at "Polkowice" station and those from other stations. As it was noted before, the measurement site in "Polkowice" was considered free from any influence from the object. Basing on the calculated differences from years 2003–2008 for specific months, some patterns can be noticed (Fig. 3). The mean air humidity measured in the morning at the "Zapora" station was lower than in "Polkowice". In the case of other stations the differences were smaller. When the difference between the values obtained from measurement sites is positive, the air humidity at the station located near the object is lower than in "Polkowice", and when it is negative then the humidity is higher. Positive differences occur during the period from October to March in "Tarnówek" and "Kalinówka", in "Rudna" only in January. During the remaining period the differences are negative and they reach the maximum value in spring and summer. For measurements taken at noon, a higher mean monthly humidity is observed at all measurement sites in May, August, September and October. At the "Zapora" station these differences are negative for most part of the study period (with the exception of January). From November to March the humidity conditions in "Tarnówek", "Kalinówka" and "Rudna" show a lower humidity than in "Polkowice". Among the measurements taken at 6 and 12 hours UTC at stations within the TP zone of influence it is difficult to find conditions most similar to those in "Polkowice". The calculation of mean monthly humidity

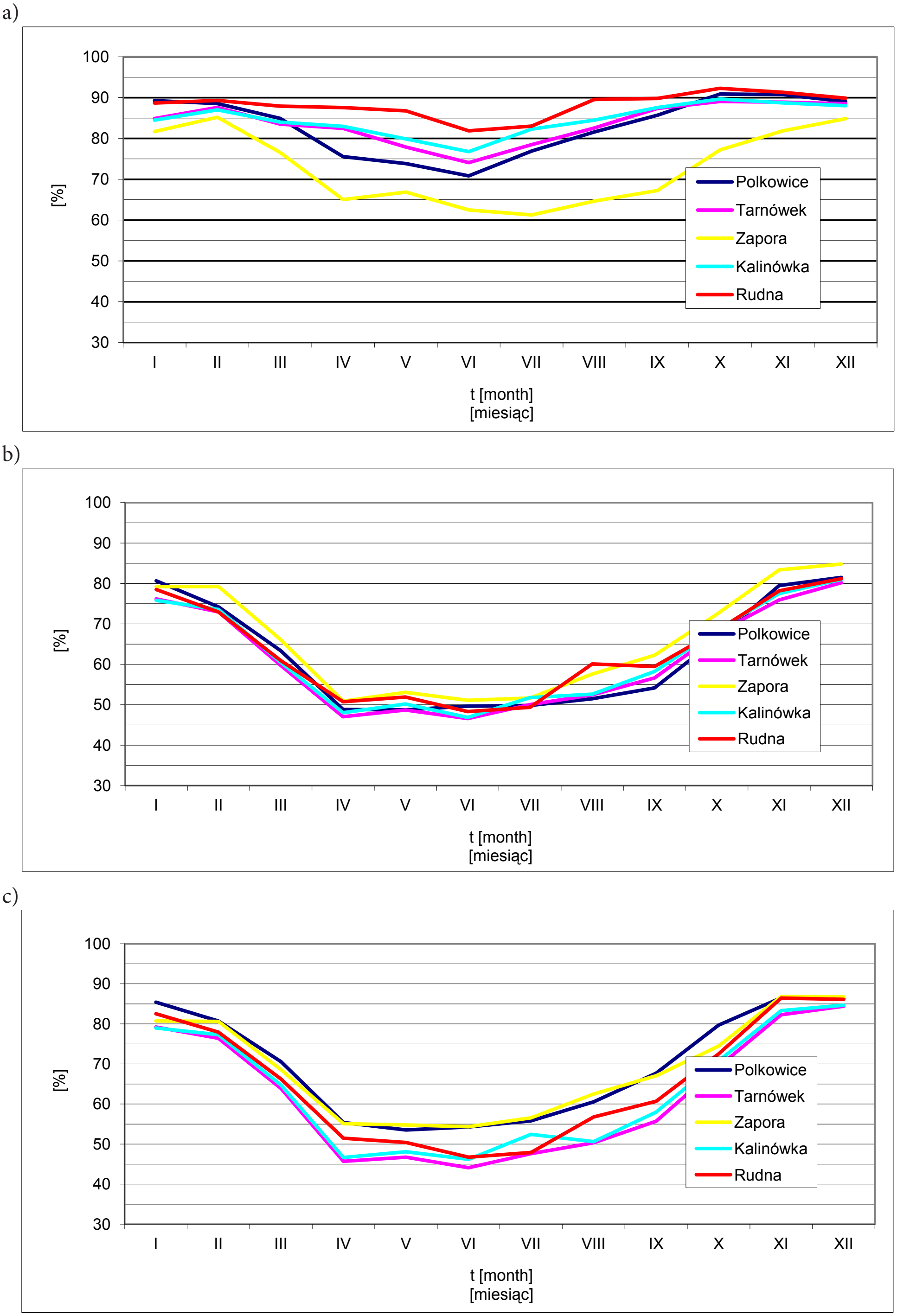


Fig. 2. The course of mean monthly values of air humidity [%] in the years 2003–2008 at hours: a) 6 UTC, b) 12 UTC, c) 18 UTC

Rys. 2. Przebieg średnich miesięcznych wartości wilgotności powietrza [%] w latach 2003–2008 o godzinie: a) 6 UTC, b) 12 UTC, c) 18 UTC basing on the evening measurements from the multi-annual period enables us to claim that the lowest differences in humidity conditions occur between "Polkowice" and "Zapora", whereas the highest differences were noted between "Polkowice" and "Tarnówek". With the exception of the "Zapora", the differences on all measurement sites are positive throughout the analysed period. On the "Zapora" positive differences occur in January, February, March, April, September and October.

The average hourly course of air humidity was analysed basing on data from the year 2005. The lowest mean periodical value of air humidity in that year occurred at 14 and 15 hours UTC at stations "Polkowice", "Tarnówek", "Kalinówka" and "Rudna", i.e. in the afternoon hours, when air temperature is the highest. In the case of the "Dam" measurement site, the minimum values are observed in the morning hours, 7 and 8 UTC. The maximum humidity is correlated with the minimum air temperature. In "Rudna" it is noted at 3–5 hours UTC, in "Polkowice" at 2–4 hours UTC, in "Tarnówek" at 5–6 hours UTC, in "Kalinówka" at approx. 6 hours UTC. The "Zapora" station shows a significant difference also in this case, as the maximum air humidity occurs during the evening and night hours, 21–0 UTC (Fig. 4).

The humidity conditions were also evaluated basing on the frequency of occurrence of air humidity values in the predefined ranges: 0–20%, 20–40%, 40–60%, 60–80% and 80–100%. The results of this analysis are presented in Figure 5.

Basing on the analysis of the frequency of occurrence of the air humidity values within predefined ranges differences were found between the analysed stations. The sources of the discrepancies are the differences in the form of thermal balance of the studied locations. On station "Polkowice", the highest frequency in the evening, night and morning hours was noted for measurements from the range 80–100%. On the other hand, measurements around noon (11–16 UTC) are most often characterized by air humidity in the range 40–60%. In the case of station "Tarnówek" values from 80–100% are most often noted between 18–10 hours UTC, 60–80% at 10–11 and 13–16 UTC. This is similar to the period when values from the top range were observed in "Kalinówka" (17–9 UTC). Measurements taken between 9 and 12 hours UTC most often fall within the range 60–80% and in the hours 14–16 UTC – 40–60%. The results of observations in "Rudna" show the highest frequency of occurrence of values from two ranges: 80–100% between 18–11 UTC and 40–60% between 12–17 UTC. This analysis shows that the most similar humidity conditions are observed on stations "Polkowice" and "Rudna". Particular attention should be paid to the "Zapora" station, where the most frequent humidity values fall within the range 80–100% throughout the analysed period.

The explanation for the influence of "Żelazny Most" on the shaping of humidity conditions in adjacent areas is the difference between heat exchange processes in water reservoirs and those on land. Such object as "Żelazny Most" causes thermal differentiation of the studied area and thus influences humidity conditions.

It should be repeated here that solar radiation is absorbed only by the superficial layer of soil, and deeper layers heat as a result of thermal conductivity, whereas in water the radiation penetrates deeper. Thermal capacity of soil is approximately two times lower than that of water, which leads to the fact that water reservoir heats and cools slower, and thus the elements of thermal balance are different.

Another factor influencing the humidity conditions is wind speed. Moreover, in the annual and daily courses it is observed that mean monthly values of air humidity for individual stations vary depending on the location of the given station in relation to the object and on the time of measurement.

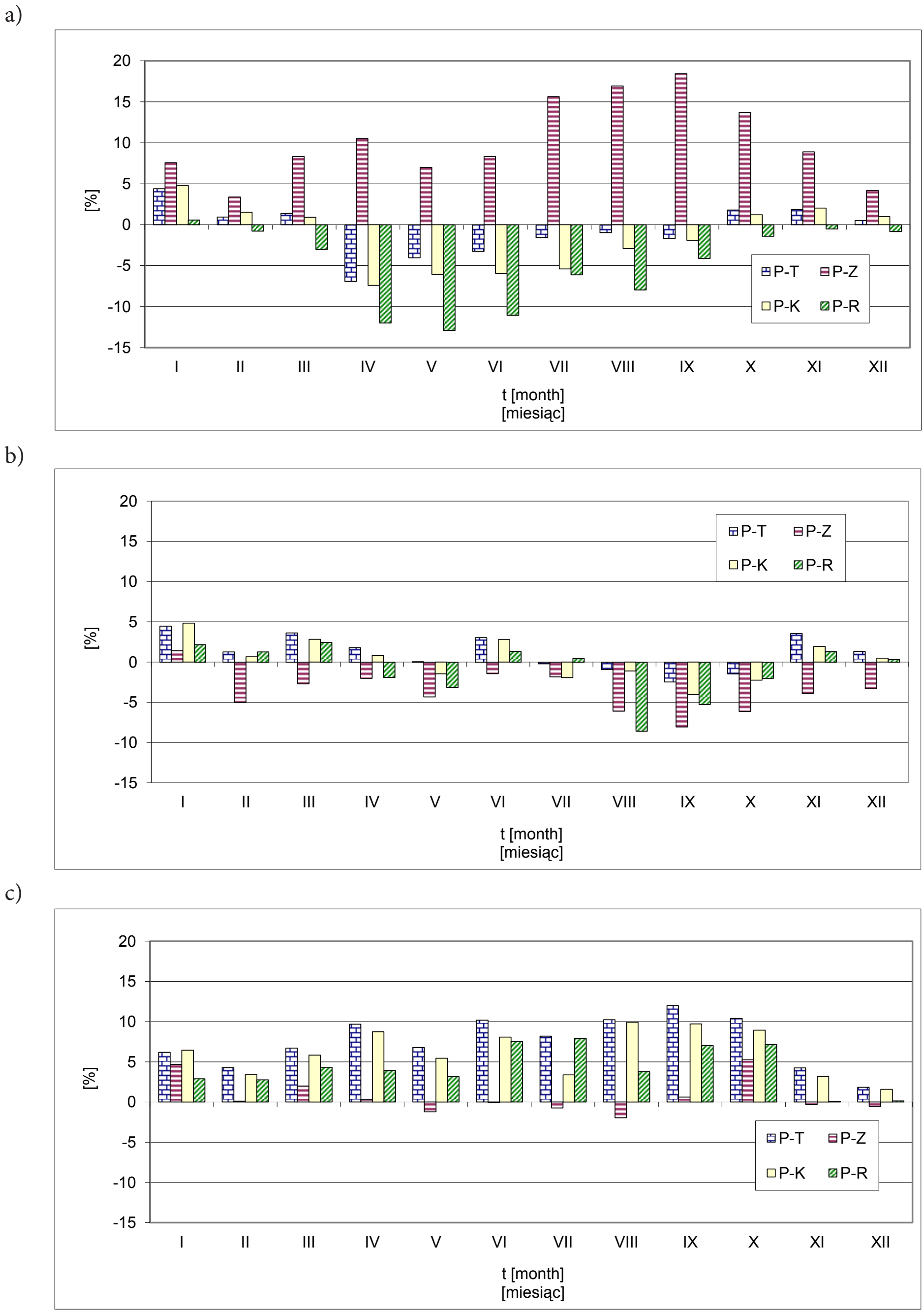


Fig. 3. Differences in mean monthly air humidity in the years 2003–2008 at hours:
a) 6 UTC, b) 12 UTC, c) 18 UTC (where: P – "Polkowice", T – "Tarnówek", Z – "Zapora",
K – "Kalinówka", R – "Rudna")

Rys. 3. Różnice średniej miesięcznej wilgotności powietrza w latach 2003–2008 o godzinie:
a) 6 UTC, b) 12 UTC, c) 18 UTC (gdzie: P – "Polkowice", T – "Tarnówek", Z – "Zapora",
K – "Kalinówka", R – "Rudna")

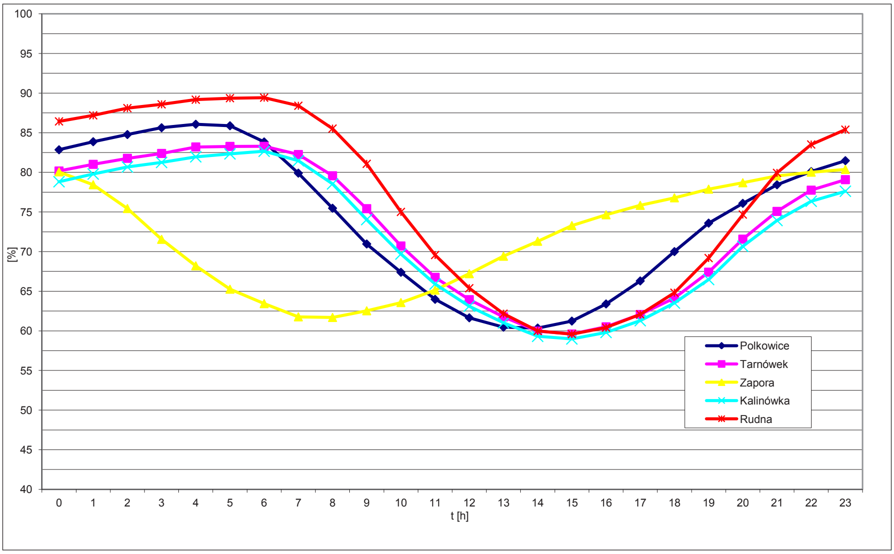
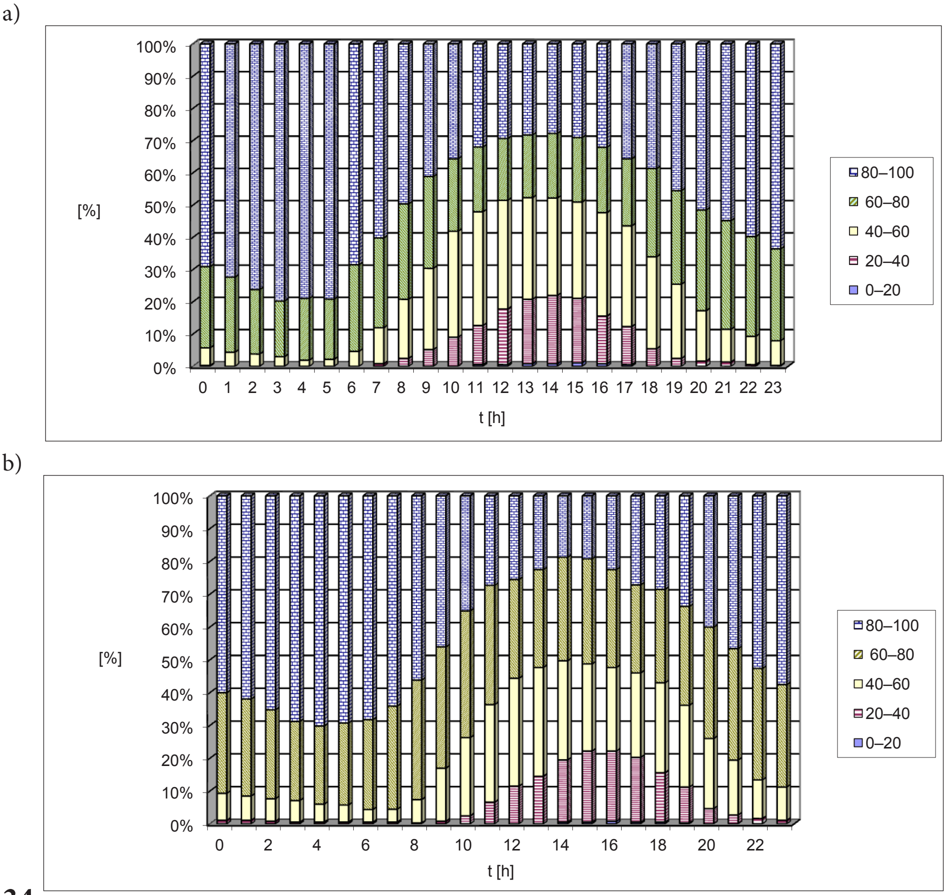


Fig. 4. Mean hourly course of the air humidity value [%] in the year 2005
Rys. 4. Średnie godzinowe przebiegi wartości wilgotności powietrza [%] w roku 2005



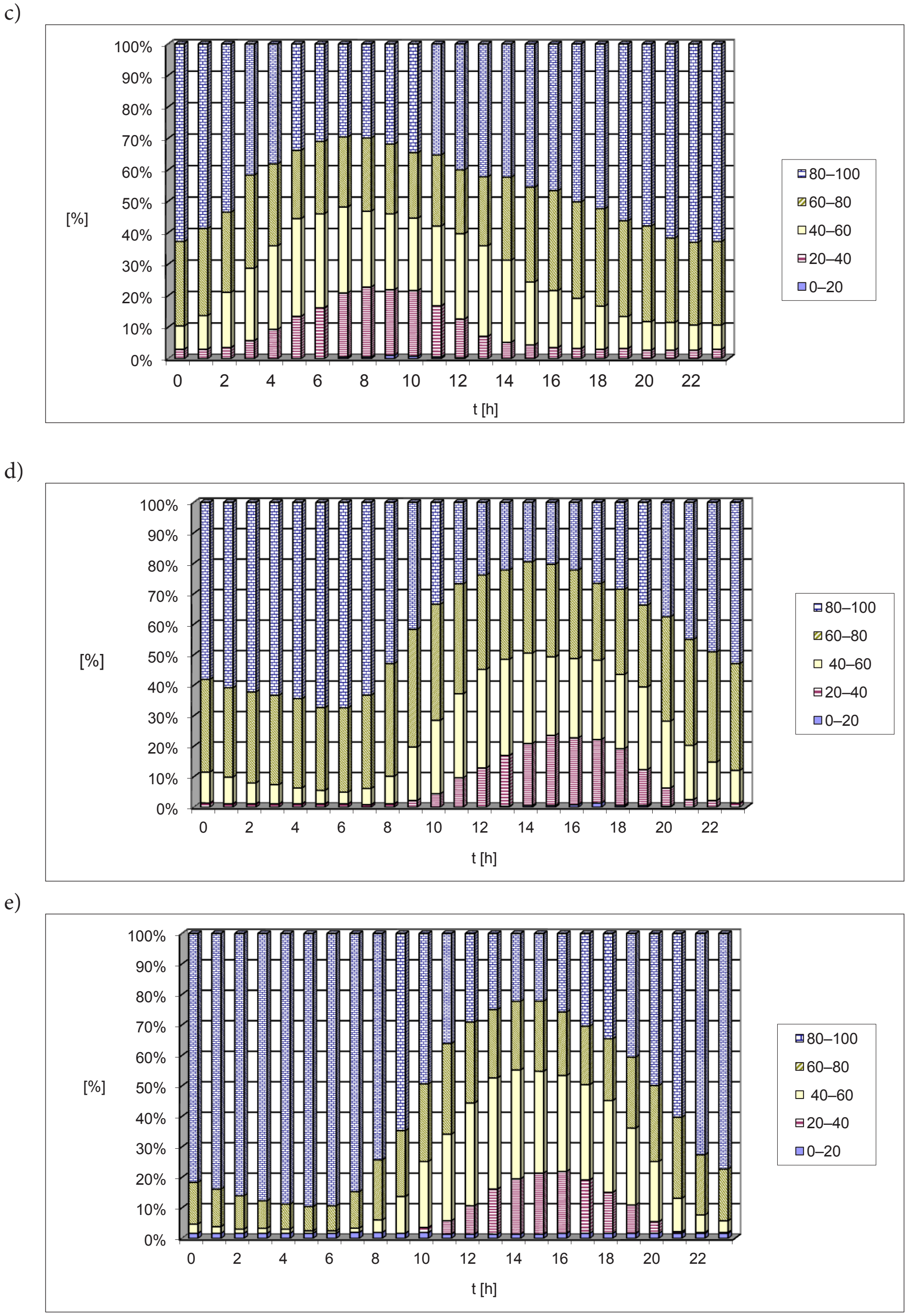


Fig. 5. Daily course of air humidity frequency [%] in specific ranges, in the year 2005 at stations: a) "Polkowice", b) "Tarnówek", c) "Zapora", d) "Kalinówka", e) "Rudna"

Rys. 5. Przebieg dobowy częstości wilgotności powietrza [%] według przedziałów w roku 2005 na stacji: a) "Polkowice", b) "Tarnówek", c) "Zapora", d) "Kalinówka", e) "Rudna"

The influence of the TP is most significant at the "Zapora" station, which is located on the beach and at the same time the closest to the reservoir. During the day, when the beach heats, humidity increases. In the morning, a significant decrease in humidity is observed. In the daily course of relative air humidity at the "Zapora" station it is noted that the daily maximum and minimum is different from that of the base station of the Institute of Meteorology and Water Management in Polkowice. "Zapora" is characterized by the lowest amplitudes of daily values. In the annual course on that station the lowest humidity values are noted during morning hours, and later in the day the values increase, so that at 12 hours UTC they are usually higher than in "Polkowice". Due to the proximity of the reservoir values from the range 80–100% occur more frequently.

In the cases of "Tarnówek" and "Kalinówka" stations, both the daily and annual courses seem highly similar. The average differences in values measured on both stations are approx. 1%. In "Tarnówek", "Kalinówka" and "Rudna" neither such noticeable shifts in the minimum and maximum values in relation to "Polkowice" nor the flattening of amplitudes was observed. The modifications of the humidity conditions at these stations are relatively small in comparison to the results from station "Polkowice".

6.2. CHARACTERISTICS OF AIR TEMPERATURE

The analysis of mean monthly air temperature in the years 2003–2008 at 6, 12, 18 hours UTC was based on the measurements taken on stations "Polkowice", "Tarnówek", "Zapora", "Kalinówka" and "Rudna". Basing on these results, certain differences in mean monthly air temperatures in the said period on specific stations were found.

The highest mean monthly air temperatures in the years 2003–2008 are noted at 12 hours UTC, and the lowest – at 6 hours UTC. In the morning the highest mean temperature occurs most frequently at "Polkowice" station, whereas at noon and in the evening – at "Rudna". On the other hand, lowest temperatures were most often noted at station "Tarnówek" – in the morning, and in "Polkowice" – at noon and in the evening. Basing on the mean monthly values, the highest temperatures occur in July (12 UTC). Minimum values are characteristic for measurements taken in January (6 UTC). It is worth noting that in the autumn period, mean temperatures at the "Zapora" increase, which is a result of the tailing pond giving back the heat. This phenomenon is clearly noticeable at the morning and evening measurement times. The highest amplitude of temperatures occurs at station "Rudna" at measurement hours 6 and 12 UTC, whereas at 18 hours UTC the highest amplitude of values in the multi-annual period was observed on station "Polkowice" (Fig. 6).

The evaluation of the influence of "Żelazny Most" on mean monthly air temperature in the analysed period was conducted basing on the differences between the results obtained from station "Polkowice" (standard and free from any influence of the object) and from the remaining stations.

Basing on the calculated differences for specific months in the period 2003–2008 (Fig. 7) it becomes obvious that the differences in results at 18 hours UTC remain negative throughout the whole range, which means that the air temperature in the zone of influence of the Tailing Pond is higher than in "Polkowice". The highest differences were noted at station "Rudna" from December to August, and at "Zapora" in the three remaining months. During the period from April to September most of the differences exceed 2°C. Lower differences, although in most cases also negative, were calculated basing on measurements taken at 12 hours UTC.

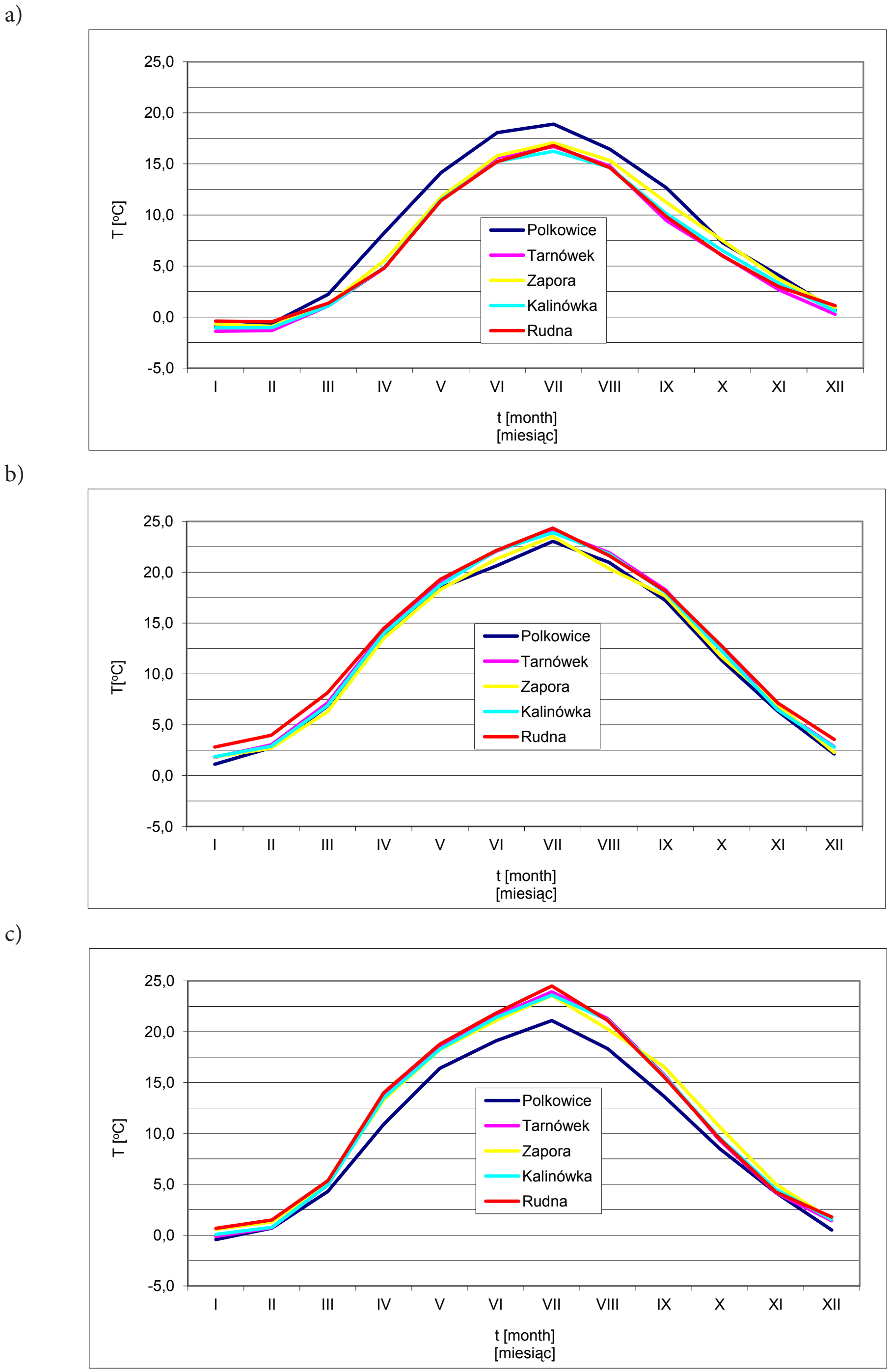


Fig. 6. Course of mean monthly air temperatures [°C] in the years 2003–2008 at hours: a) 6 UTC, b) 12 UTC, c) 18 UTC

Rys. 6. Przebieg średnich miesięcznych wartości temperatury powietrza [°C] w latach 2003–2008 o godzinie: a) 6 UTC, b) 12 UTC, c) 18 UTC

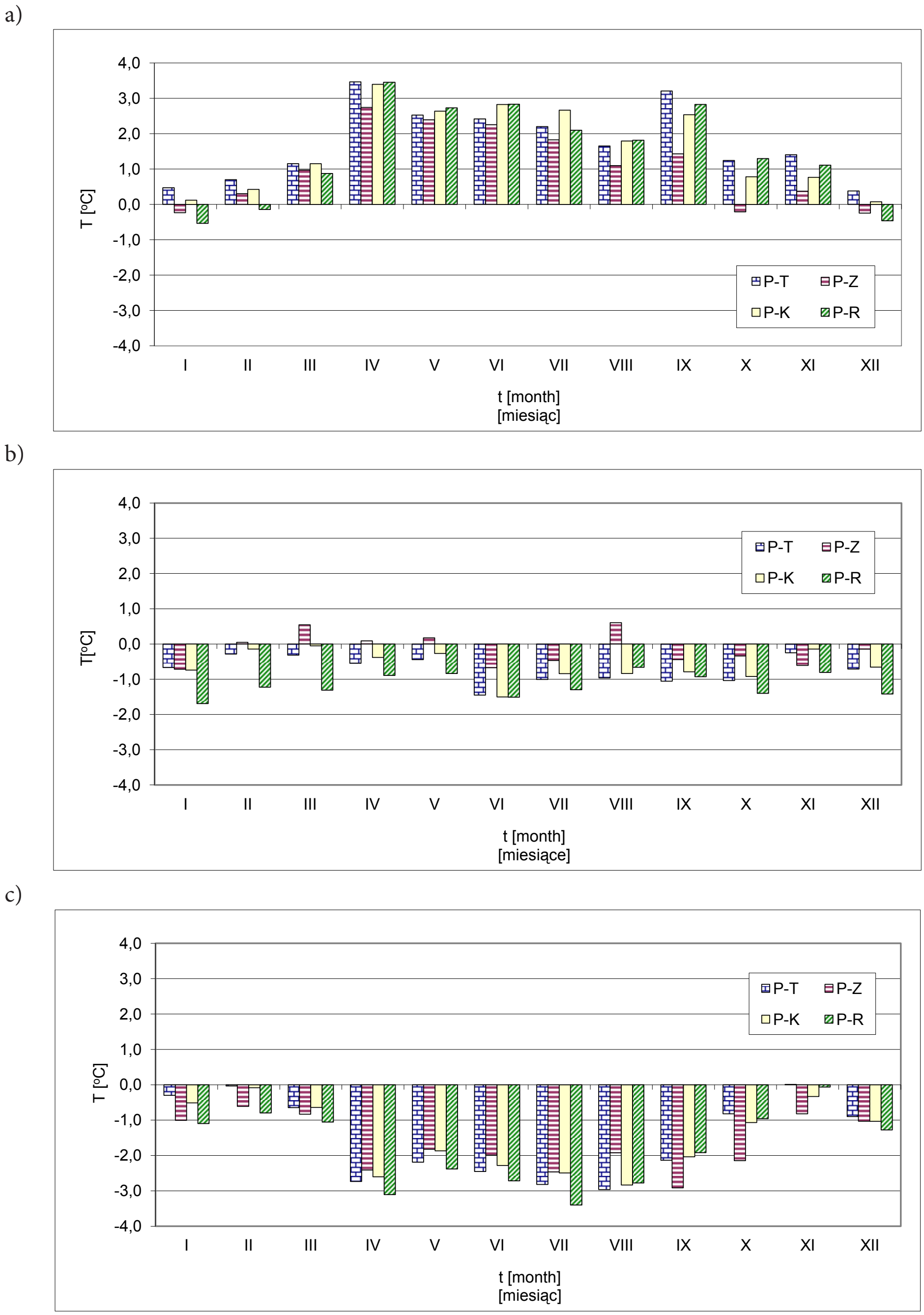


Fig. 7. Differences in mean monthly air temperature in the years 2003–2008 at hours: a) 6 UTC, b) 12 UTC, c) 18 UTC (where: P – "Polkowice", T – "Tarnówek", Z – "Zapora", K – "Kalinówka", R – "Rudna")

Rys. 7. Różnice średniej miesięcznej temperatury powietrza w latach 2003–2008 o godzinie: a) 6 UTC, b) 12 UTC, c) 18 UTC (gdzie: P – "Polkowice", T – "Tarnówek", Z – "Zapora", K – "Kalinówka", R – "Rudna")

With the exception of May, when the highest difference is characteristic for "Zapora" and September, when it occurs in "Tarnówek", the highest frequency of negative differences occurs at the observation site "Rudna". Cooler thermal conditions than in Polkowice are noted at stations within the zone of influence of "Żelazny Most" in March, April and August on the Dam, and in May at stations "Zapora", "Kalinówka" and "Rudna". Measurements taken at 6 hours UTC are characterized by the highest frequency of positive differences. The highest values are reached in the months from April to September. It should be pointed out that in the same period the relation between "Polkowice" and "Zapora" is determined by the lowest values of differences. Negative differences occur rarely, proving that the temperature within the zone of influence of "Żelazny Most" is lower in October at the "Zapora", in December and January on "Zapora" and in "Rudna" and in February in "Rudna". During the period from December to February these differences are small (less than 1°C).

The daily course of mean hourly air temperature in 2005 is shown in Figure 8. The analysis of mean hourly values of air temperature in 2005 shows that minimum temperatures occur most frequently at 5 hours UTC, at stations "Rudna", "Kalinówka" and "Tarnówek", 7 UTC at station "Zapora", and in Polkowice at 4 hours UTC, whereas the maximum values occur most frequently at 15 hours UTC at stations "Rudna", "Kalinówka", "Tarnówek" and "Zapora". The measurements from "Polkowice" show a maximum at 13 hours UTC.

The evaluation of thermal conditions was also based on the analysis of frequency of occurrence of air temperatures in the predefined ranges: < (-20), (-20)–(-10), (-10)–0, 0–10, 10–20, 20–30, > 30°C. The results of this analysis are presented in Figure 9.

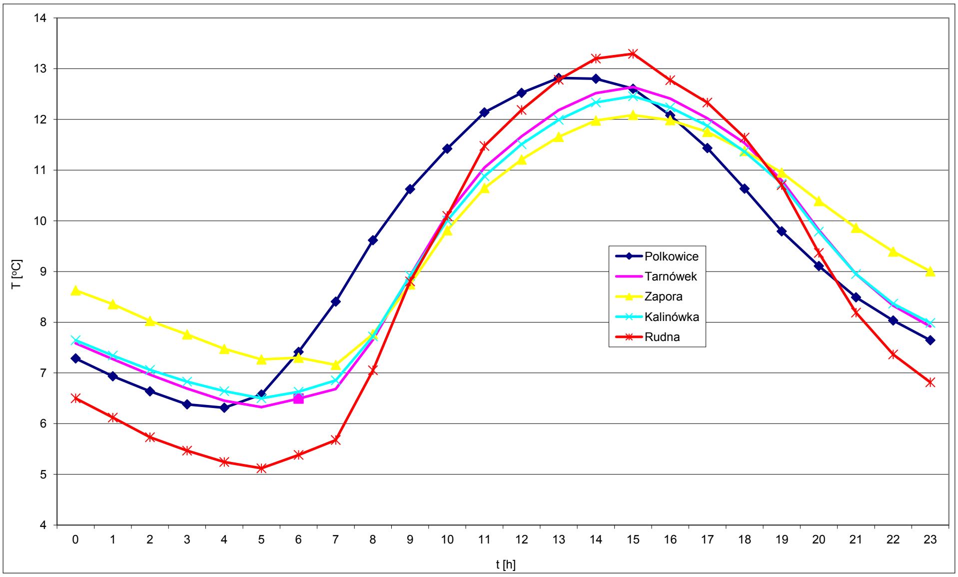
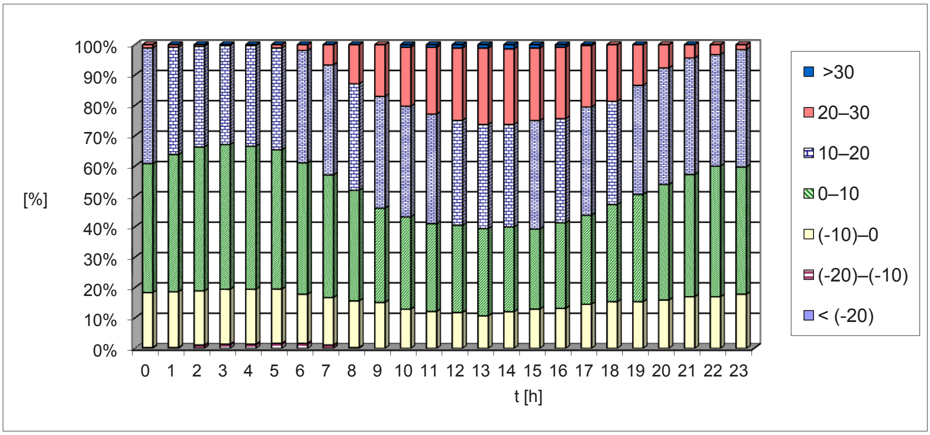


Fig. 8. Mean hourly courses of air temperature values [°C] in 2005
Rys. 8. Średnie godzinowe przebiegi wartości temperatury powietrza [°C] w roku 2005

a)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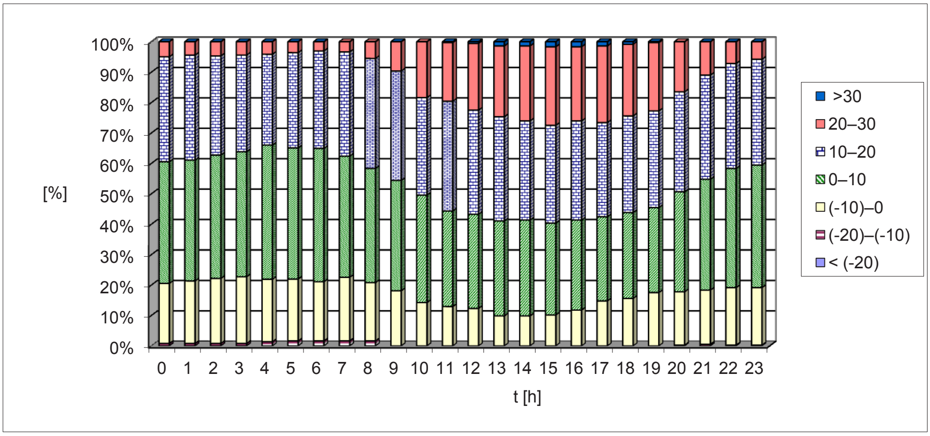
< (-20)

b)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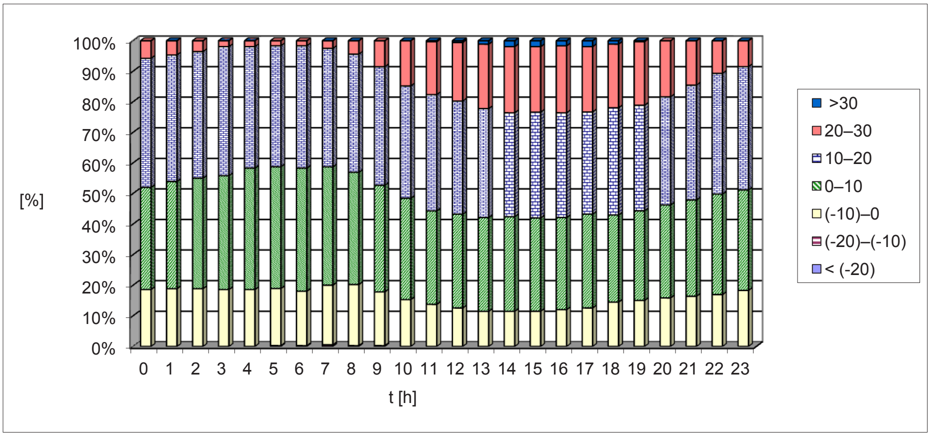
c)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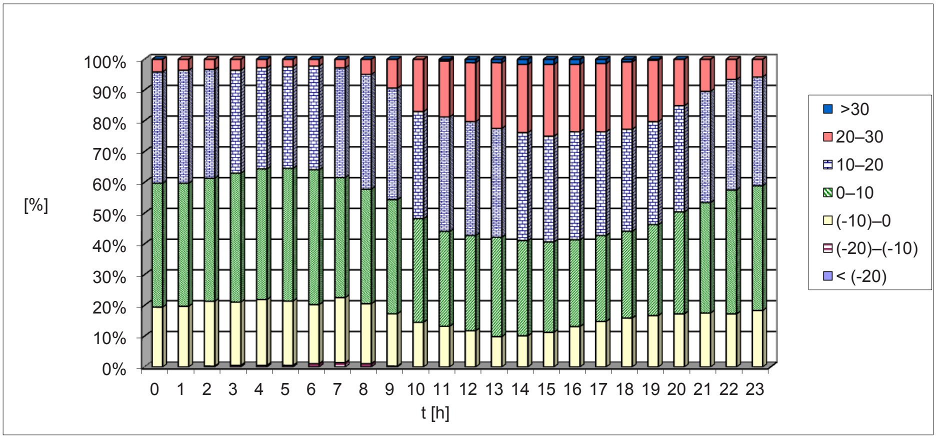
d)



e)

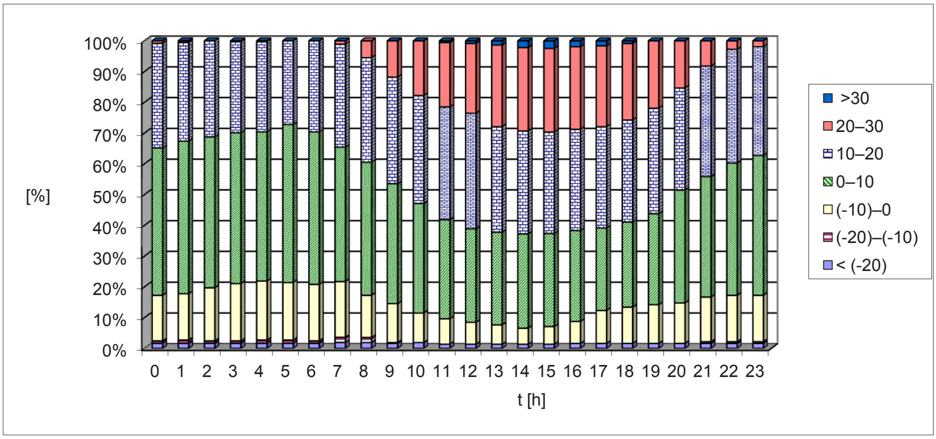


Fig. 9. Daily course of frequency of air temperatures [°C] in specific ranges in 2005 at stations: a) "Polkowice", b) "Tarnówek", c) "Zapora", d) "Kalinówka", e) "Rudna"
Rys. 9. Przebieg dobowy częstości temperatury powietrza [°C] według przedziałów w roku 2005 na stacji: a) "Polkowice", b) "Tarnówek", c) "Zapora", d) "Kalinówka", e) "Rudna"

The frequency analysis shows that the highest frequencies were observed for measurements falling into two ranges: 0–10°C and 10–20°C. The first one is typical for measurements in the evening hours, through night until the morning, whereas the second one describes measurements recorded during daytime. In "Polkowice" the most frequently noted temperatures in the range 0–10°C were measured from 20 to 8 hours UTC, and in the range 10–20°C – from 9 to 19 hours UTC. A similar situation was observed in "Rudna" and "Tarnówek", although at these stations the period when temperatures in the range 0 to 10°C were most frequent lasted until 10 hours UTC. On the other hand, in "Kalinówka" temperatures from the range 0–10°C were most frequently recorded from 22–9 UTC, and 10–20°C – from 10 to 21 UTC. The measurement site "Zapora" is different due to the fact that temperatures from the range 10–20°C were dominant throughout the day. "Zapora" is also characterized by the lowest frequency of measurements < -10°C.

Daily course of air temperature is influenced by solar radiation. The highest amount of solar energy reaches the earth at the point of solar culmination. At that moment, the temperature reaches the peak. During the period when the amount of incoming solar radiation is higher than the amount of lost radiation, temperature rises. The minimum occurs approximately at the moment of sunrise. Until that time, the surface of land cools down, while at the same time it does not receive any solar radiation during the night. From the moment of sunrise, the incoming solar radiation starts to exceed the loss, so that the air temperature starts to rise until it reaches the maximum around noon. Such daily temperature course is presented in data obtained from "Polkowice". This station is a part of the standard observation network of the Institute of Meteorology and Water Management. It is assumed that the thermal conditions correspond to natural climate conditions in this part of Lower Silesia and are not affected by any additional factors.

The analysis of the measurement results obtained from stations "Tarnówek", "Zapora" and "Kalinówka" shows a decrease in the daily amplitude in comparison to "Polkowice". This difference is most visibly manifested on the embankment crown of the TP. The measurement site "Rudna" is characterised by an increase in the daily amplitude. There is also a noticeable shift in the average time of occurrence of daily minimum and maximum temperatures. In "Tarnówek", "Kalinówka" and "Rudna" the maximum and minimum daily values are, on the annual average, delayed by 2 hours, whereas on the "Zapora" the daily minimum is moved by 3 hours, and the maximum by 2 hours in comparison to "Polkowice". The property that distinguishes the measurement site "Zapora" from the other stations is also the highest frequency of occurrence of temperatures within the range 10–20°C and the lowest frequency of occurrence of temperatures below 0°C.

Some aspects of the annual cycle of temperature changes resemble the daily cycle, as the latter is influenced by the annual cycle of changes in incoming solar radiation. Due to that, highest temperatures occur in summer, and the lowest in winter. The differences between the station "Polkowice" and measurement sites located within the zone of influence of "Żelazny Most" are the most visible in the morning hours, when the mean temperatures recorded at stations "Tarnówek", "Zapora", "Kalinówka" and "Rudna" are lower, and in the evening, when the measured temperatures are higher. In autumn, an increase in the temperatures measured at those times is observed at "Zapora" in comparison to "Tarnówek", "Kalinówka" and "Rudna".

The observed changes in thermal conditions in the studied area are rather small and they involve mainly the decrease of both daily and annual amplitudes, the shift in the time of occurrence of minimum and maximum temperatures and a lowering of the maximum value along with an increase of the minimum value [Zapart 2008]. It is worth noting that "Żelazny Most" is characterised by a high thermal capacity. In the spring, the reservoir constituting the central part of the TP begins to store heat, hence the lowered temperature on the embankment crown and in adjacent areas from spring to summer. In the autumn, when temperatures start to fall, "Żelazny Most" begins to emit the stored heat. This phenomenon is most clearly visible in the daily course of temperature at the "Zapora" station. A similar cycle of heating and then emission of thermal energy takes place during the day and at night.

6.3. CHARACTERISTICS OF WIND SPEED

The measurements of wind speed from the years 2003–2008 enable us to evaluate the variability of mean monthly wind speed at 6, 12, 18 hours UTC. In the discussed area some spatial differentiation of wind speed is noticed. The highest mean values from the analysed period are noted at the "Zapora" station at noon, whereas in the morning and evening measurement hours these values are lower. The lowest mean monthly wind speed is recorded in "Polkowice" at 18 hours UTC. At the other measurement hours the values measured in "Polkowice", "Tarnówek", "Kalinówka" and "Rudna" are similar.

The course of mean monthly values in the years 2003–2008 shows some fluctuations. They point to some tendencies connected with the daily and annual cycles. Evening and midday observations (from July to February) show that the lowest values are characteristic for the conditions in Polkowice. Moreover, for measurements taken at 12 and 18 hours UTC also an increase in wind speed is observed at station "Kalinówka" in comparison to "Tarnówek", while at 6 hours UTC this relation is reversed (Fig. 10) [Zapart 2010]. The above findings are confirmed by the analysis of data from individual years in the period from 2003 to 2008.

The influence of "Żelazny Most" on wind speed is evaluated basing on the differences between the conditions measured at the station of Institute of Meteorology and Water Management in Polkowice and the conditions at the remaining stations (Fig. 11). The differences between mean monthly values recorded at "Polkowice" and "Zapora" are negative for all measurement hours. This proves that the wind speed is higher on the crown of the embankment of the TP. The highest differences were recorded for measurements at 18 hours UTC (the maximum difference occurred in August: 3.2 $m \cdot s^{-1}$), while the lowest were noted for measurements taken at 6 hours UTC. For measurements taken in the morning, lower wind speed than in "Polkowice" was recorded at "Kalinówka" and "Rudna" in the following months: April, June, July, September and October, while in "Tarnówek" in April and June. These differences are the highest in April and June, although they do not exceed 1 $m \cdot s^{-1}$. Data recorded at 12 hours UTC show that the mean values of wind speed are lower in "Tarnówek" and "Rudna" measurement points than in "Polkowice" only in two of the analysed months: April and June. Throughout the remaining period these differences are negative. Evening measurements show that the wind speed values in the zone of influence of "Żelazny Most", are higher than at the reference station nearly throughout the whole measurement period. The exceptions from the above pattern are observations from February and March taken at "Tarnówek" and in January and October at station "Kalinówka" (the differences do not exceed 0.3 $m \cdot s^{-1}$).

The course of mean hourly wind speed at the discussed stations is shown in Figure 12. The highest wind speed throughout the day is characteristic for the measurement site on the crown of the embankment ("Zapora"). Mean wind speed measured on the "Zapora" in 2005 is at least 1 $m \cdot s^{-1}$ higher than at the remaining stations. On the other hand, the lowest values are recorded in "Polkowice" through a major part of the analysed period. The exception are the hours from 6 UTC to 10 UTC, when the lowest speed is measured at "Rudna" and, temporarily, at "Kalinówka".

The comparison of the measurements recorded at "Tarnówek" and "Kalinówka" shows that throughout a major part of the measurement period higher wind speed is recorded in "Tarnówek" along with a simultaneous flattening of daily amplitude. Special attention should be paid to the measurement times from 11–16 UTC, when slightly higher values of wind speed are recorded at "Kalinówka". These stations are located in similar topographic conditions, and the property that differentiates them is the location in relation to geographical directions.

The daily maximum wind speed is recorded for all stations during the hours from 11 UTC to 16 UTC. After that time, a decrease in wind speed is observed, and another increase is recorded only at approximately 6 hours UTC.

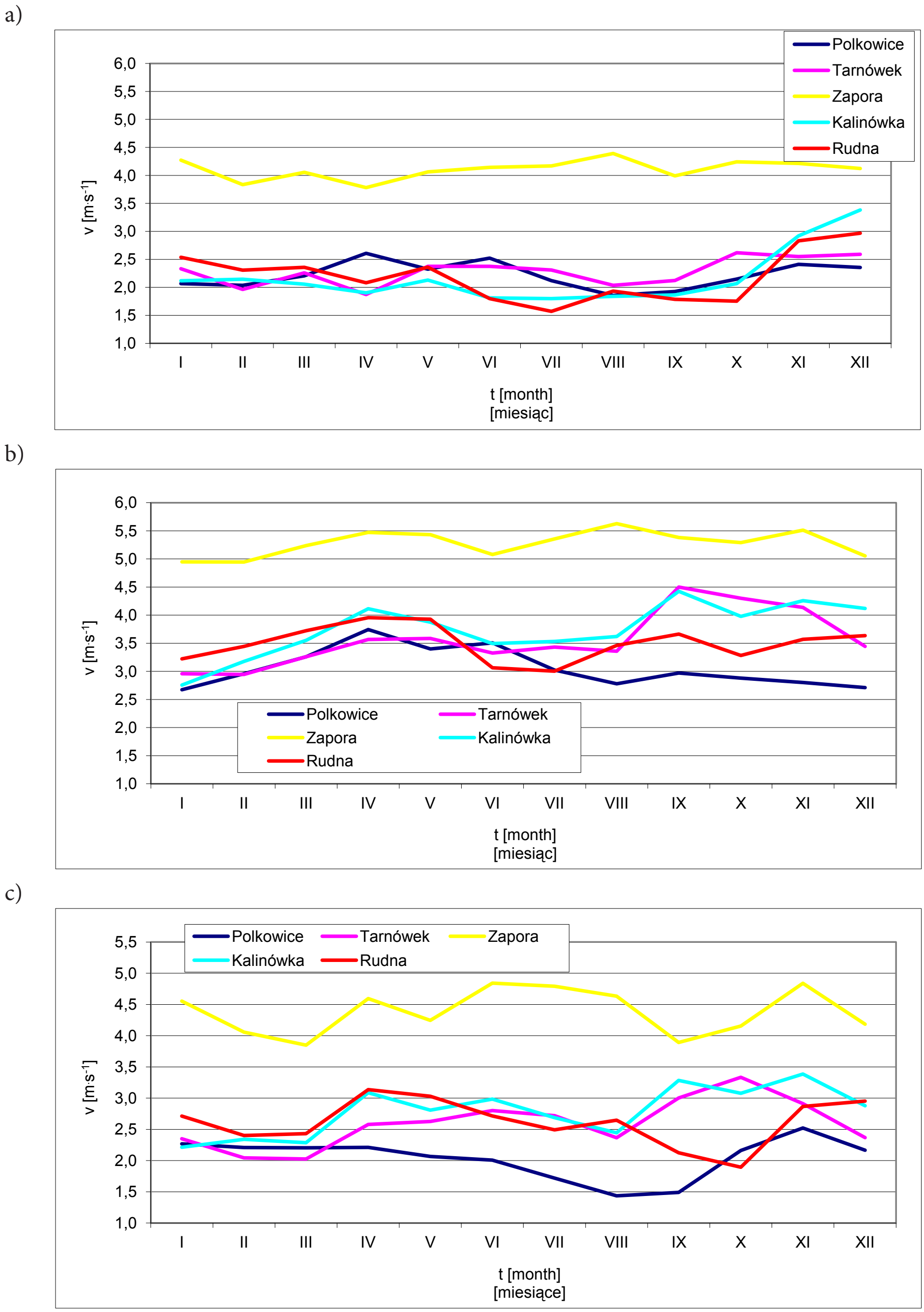


Fig. 10. The course of mean monthly values of wind speed [m·s^{-1}] in the years 2003–2008 at hours: a) 6 UTC, b) 12 UTC, c) 18 UTC

Rys. 10. Przebieg średnich miesięcznych wartości prędkości wiatru [m·s^{-1}] w latach 2003–2008 o godzinie: a) 6 UTC, b) 12 UTC, c) 18 UTC

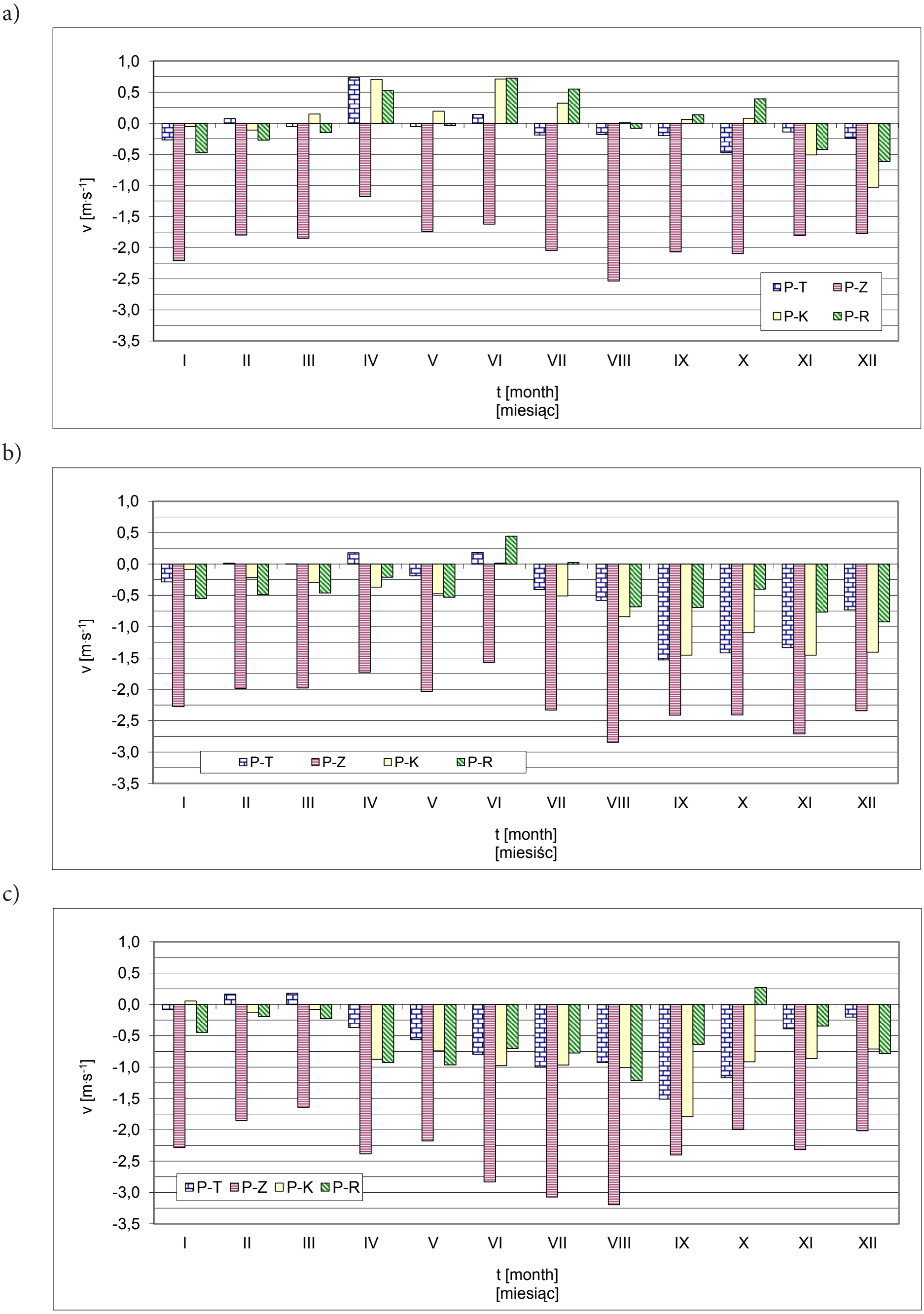


Fig. 11. Differences in mean monthly wind speed in the years 2003–2008 at hours:
a) 6 UTC, b) 12 UTC, c) 18 UTC (where: P – "Polkowice", T – "Tarnówek", Z – "Zapora", K – "Kalinówka", R – "Rudna")

Rys. 11. Różnice średniej miesięcznej prędkości wiatru w latach 2003–2008 o godzinie:
a) 6 UTC, b) 12 UTC, c) 18 UTC (gdzie: P – "Polkowice", T – "Tarnówek", Z – "Zapora", K – "Kalinówka", R – "Rudna")

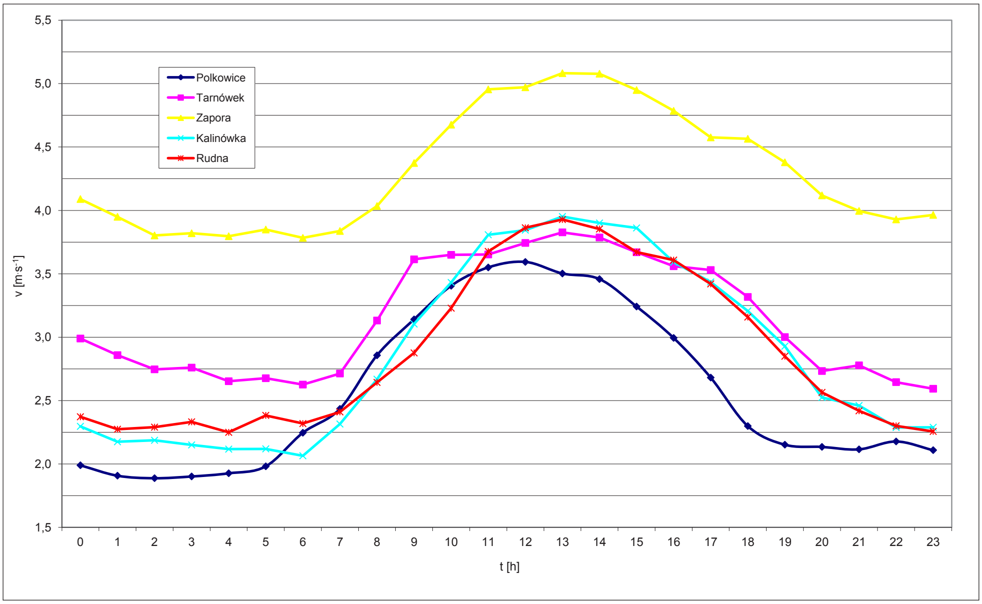
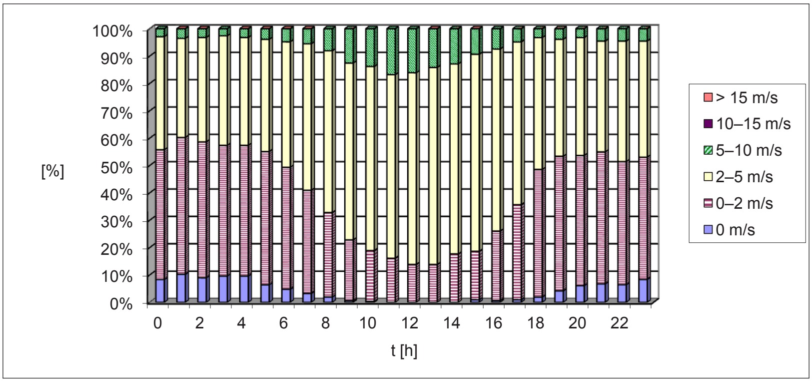


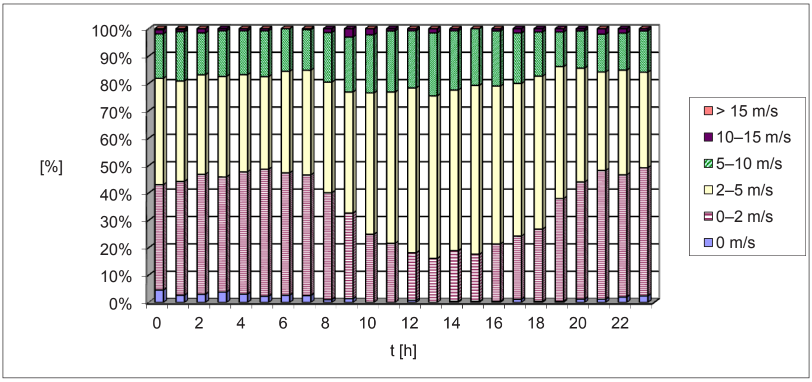
Fig. 12. Mean hourly courses of wind speed [m·s^{-1}] in the year 2005

Rys. 12. Średnie godzinowe przebiegi wartości prędkości wiatru [m·s^{-1}] w roku 2005

a)



b)



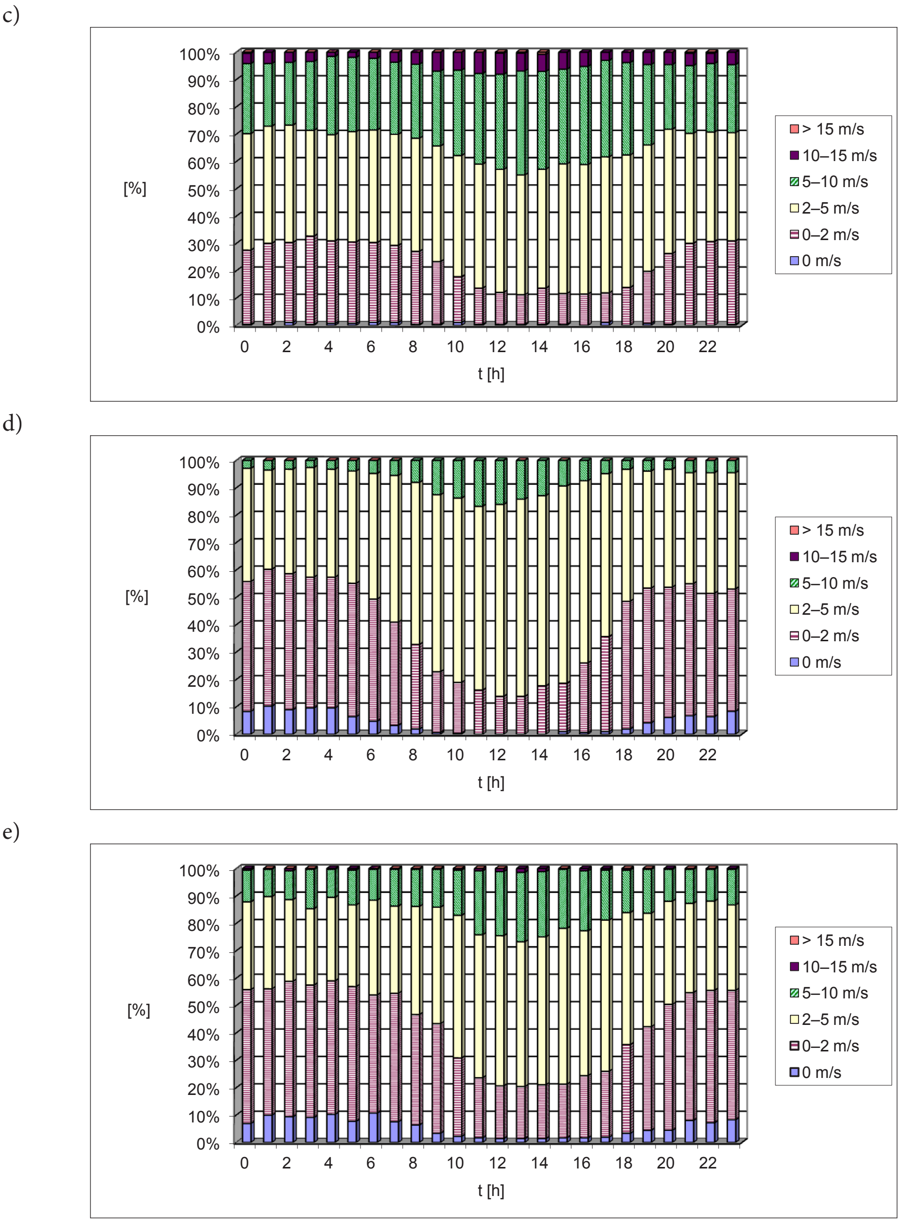
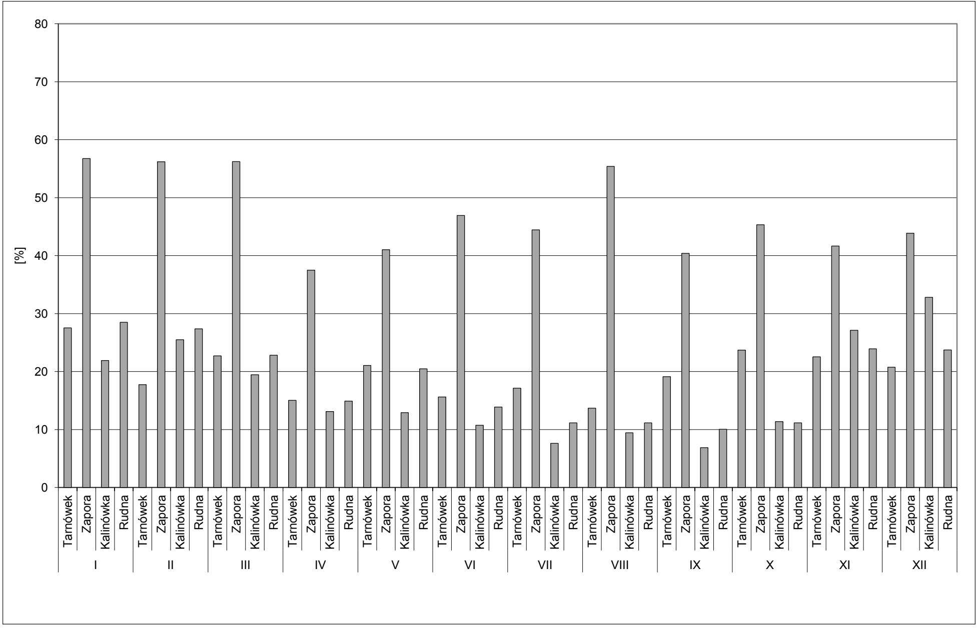


Fig. 13. Daily course of frequency of wind speed [m·s^{-1}] in specific ranges in the year 2005 at stations: a) "Polkowice", b) "Tarnówek", c) "Zapora", d) "Kalinówka" e) "Rudna"

Rys. 13. Przebieg dobowy częstości prędkości wiatru [m·s^{-1}] według przedziałów w roku 2005 na stacji: a) "Polkowice", b) "Tarnówek", c) "Zapora", d) "Kalinówka" e) "Rudna"

a)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30
20
10
0
[%]
Tarnówek
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VI
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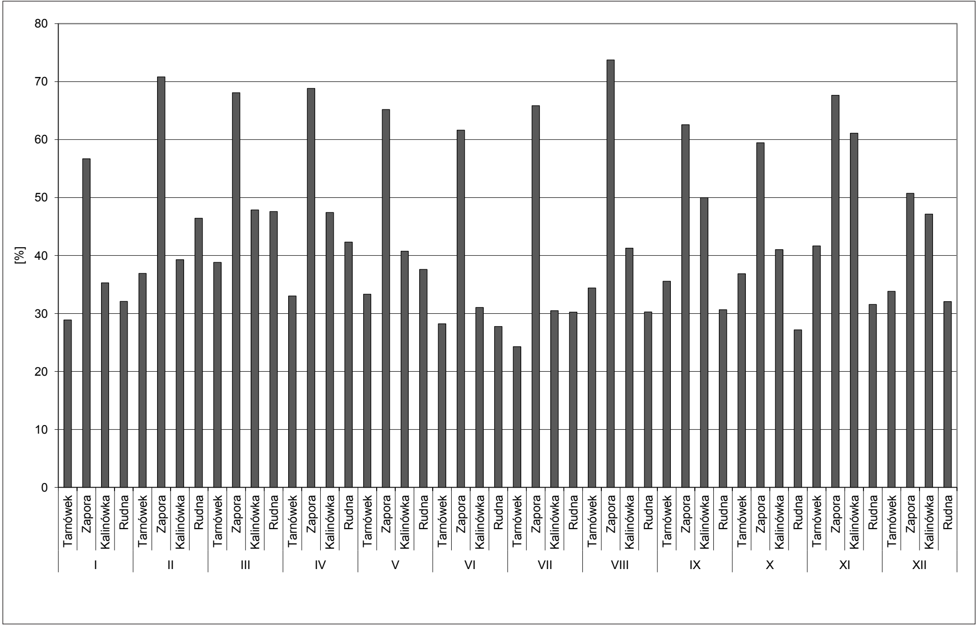
IX
X
XI
XII

b)


80
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c)

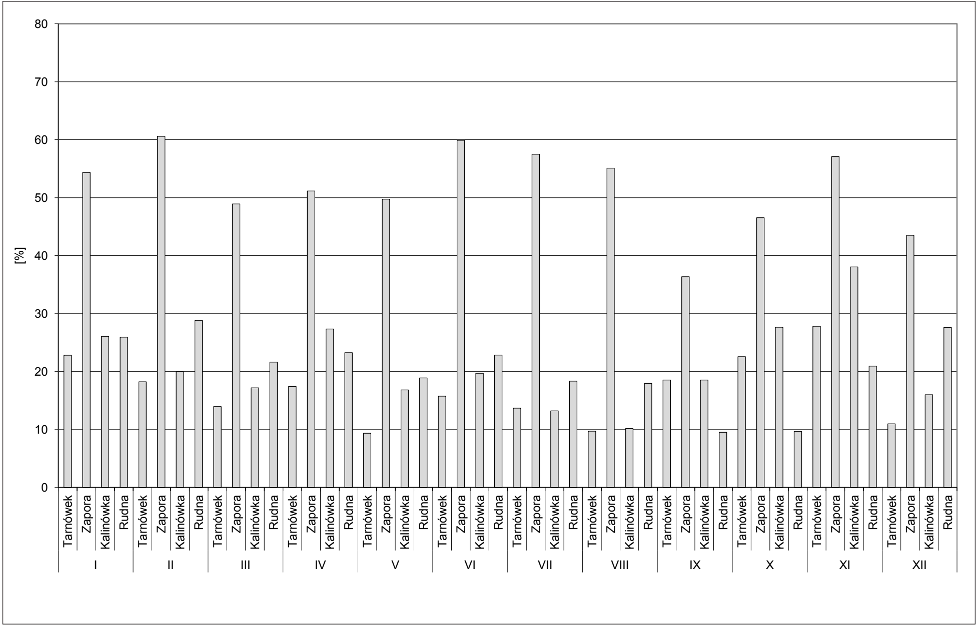


Fig. 14. Frequency of occurrence of wind speed > 4 m·s^{-1} in the years 2003–2009 at hours: a) 6 UTC, b) 12 UTC, c) 18 UTC

Rys. 14. Częstość wystąpienia prędkości wiatru > 4 m·s^{-1} w latach 2003–2009 o godzinie: a) 6 UTC, b) 12 UTC, c) 18 UTC

This study also evaluates the frequency of occurrence of wind speed in predefined ranges. For the purposes of such evaluation, the author used the following ranges of wind speed, suggested by Bartnicki [1930]:
V = 0 m·s^{-1} – calms,
0 m·s^{-1} – 2 m·s^{-1} – very weak winds,
2 m·s^{-1} – 5 m·s^{-1} – weak winds,
5 m·s^{-1} – 10 m·s^{-1} – moderate winds,
10 m·s^{-1} – 15 m·s^{-1} – strong winds,
V > 15 m·s^{-1} – very strong winds.

The results of this evaluation are presented in form of frequency diagrams (Fig. 13).

Weak winds (2–5 m·s^{-1}) are most frequently recorded at all stations, followed by very weak winds (0–2 m·s^{-1}), moderate winds (5–10 m·s^{-1}) and calms (0 m·s^{-1}). At the measurement sites "Tarnówek" and "Kalinówka" single values from the range 10–15 m·s^{-1} were also recorded. Winds from the latter range are certainly most frequently recorded at the "Zapora". Measurements taken at this station also show the occasional occurrence of very strong winds (> 15 m·s^{-1}). Calms are rarely recorded at this measurement site.

The performed calculations also show that wind speed 2–5 m·s^{-1} occurs most frequently during daytime, whereas winds from the range 0–2 m·s^{-1} occur usually at night. This correlation is noticeable for measurements at all sites. The occurrence of calms also seems related to the time of day, as calms are most often recorded between 18 and 6 hours UTC.

The obtained results prove that the changes in wind speed are influenced by the tailing pond "Żelazny Most". The main cause is considered to be the change in the friction coefficient and the change in terrain formation in comparison to surrounding areas. Wind speed increases within the zone of influence of the object. This phenomenon is particularly visible on the surface of "Żelazny Most", where a significant increase in wind speed and a decrease in the number of atmospheric calms is observed both in multi-annual and daily scale. This relation is observed at a lesser extent on the measurement sites installed at the foot of the object.

The most important factor influencing the increase in wind speed on "Żelazny Most" is the lowering of the roughness coefficient in comparison to the surrounding areas. The surface of the object is a flat area with a pond in its central part, and, apart from the towers with installations for the re-circulation of oversedimentary waters, there are no other objects increasing superficial friction. Also, the elevation of the object above the adjacent area contributes to the increase in wind speed.

The evaluation of the influence of the tailing pond on wind conditions at stations "Tarnówek" and "Kalinówka" should take into account the direction of the wind. The analysis shows that, during the most frequent western winds, the wind speed before the object increases (station "Tarnówek") while it decreases after the object (station "Kalinówka"). This is a result of the phenomenon of air flowing around the obstacle. Lower wind velocities at the level of 10 m in "Tarnówek", "Kalinówka" and "Rudna" are also connected with higher surface friction as these stations are installed in an area covered mainly by grasslands and meadows, with single bushes and trees growing at a large distance apart from each other [Flaga 2008].

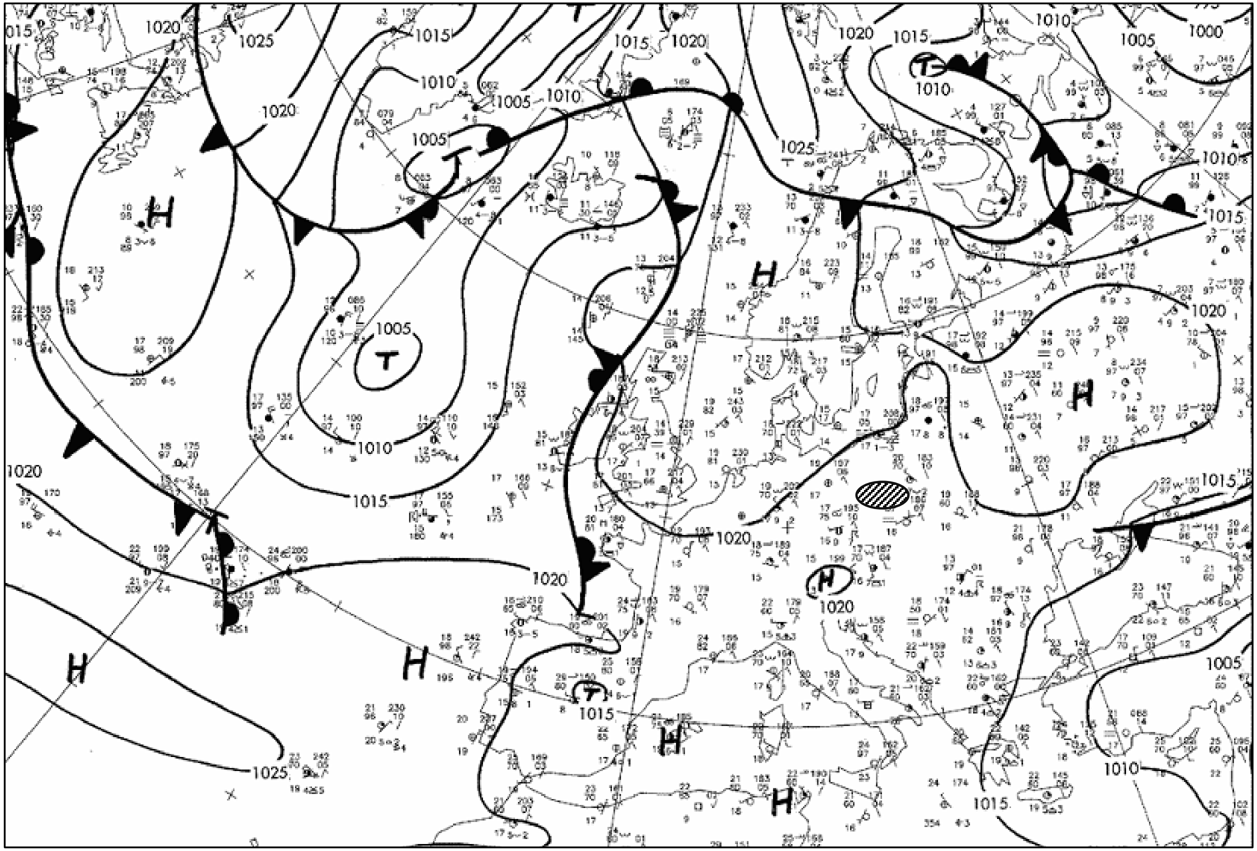
The above described wind conditions in the layer of atmosphere adjacent to the ground influence the temperature and humidity conditions. The increase in wind speed leads to the intensification of heat exchange between the surface and the air.

The analysis also encompassed the frequency of occurrence of wind speed exceeding 4 $m{\cdot}s^{-1}$, at stations "Tarnówek", "Zapora", "Kalinówka" and "Rudna" at main measurement hours 6, 12 and 18 UTC, in the years 2003–2009. This is an important value as it is connected with the occurrence of eolian processes on the surface of the object. The analysis shows that such values appear most frequently in data from measurements taken at 12 hours UTC in March, April, September, October and November, and most rarely – in the morning in July, August and September. The highest frequency of occurrence of wind speed exceeding this value is recorded at station "Zapora", at noon. This number exceeds 50% of all recorded measurements (Fig. 14) [Zapart 2010].

6.4. VARIABILITY OF TEMPORARY VALUES OF AIR HUMIDITY AND TEMPERATURE AND WIND SPEED THROUGHOUT THE DAY

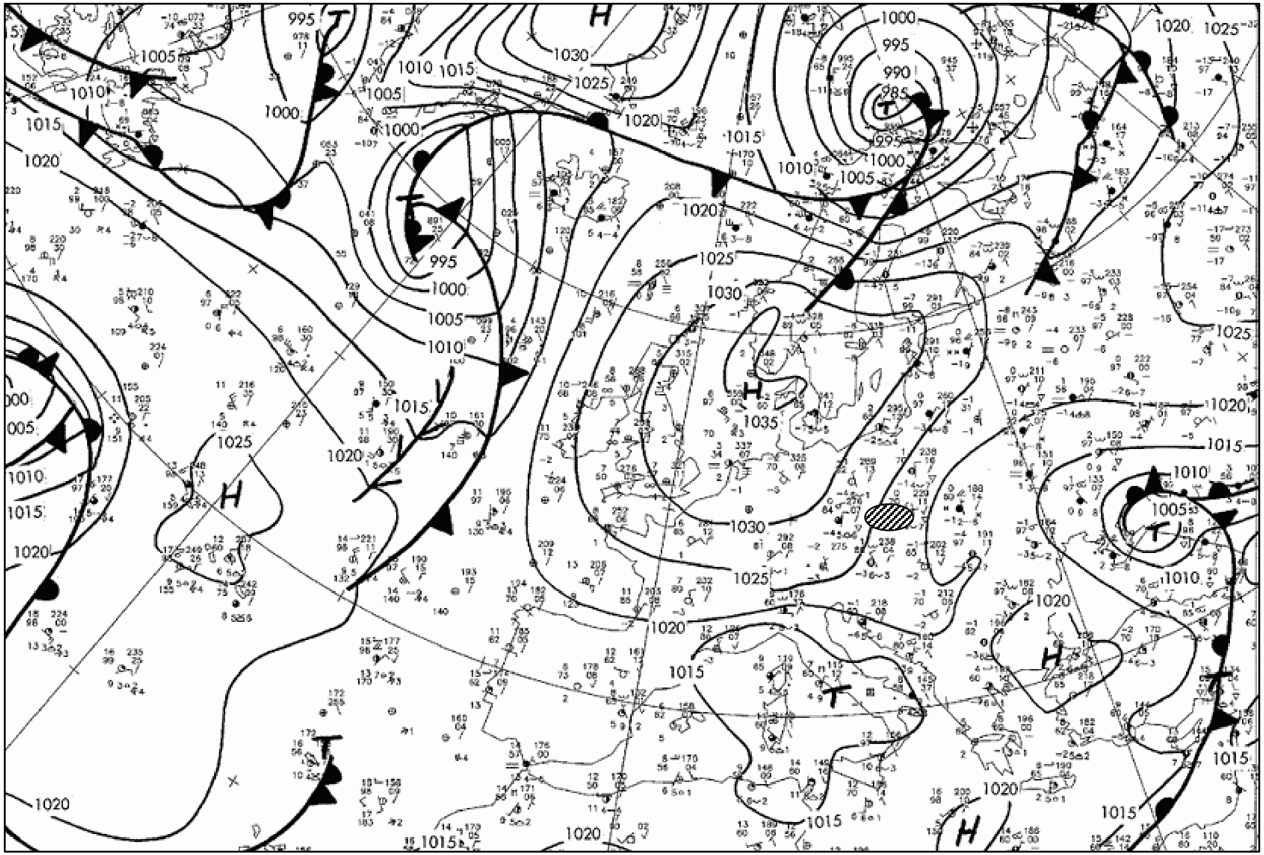
In climatology it is assumed that the variability in local climate is manifested to the greatest extent during cloud-free weather with high solar radiation [Chromow 1969]. Such conditions occur when the studied area remains under the influence of an anticyclone from the northern or north-eastern areas of the continent.

For the purposes of this study two days were isolated representing anticyclonic weather in the warm season (IV–X) and the cold season (XI–III). The synoptic conditions from these periods are presented in Figures 15 and 16.



▨ analysed area – obszar badań

Fig. 15. Synoptic map of Europe of the 2nd of July, 2009 (source: www.wetter3.de)
Rys. 15. Mapa synoptyczna Europy z dnia 2 lipca 2009 r. (źródło: www.wetter3.de)



▨ analysed area – obszar badań

Fig. 16. Synoptic map of Europe of the 20th of March, 2009 (source: www.wetter3.de)
Rys. 16. Mapa synoptyczna Europy z dnia 20 marca 2009 r. (źródło: www.wetter3.de)

The analysis of temporary values of air humidity at stations "Tarnówek", "Zapora" and "Kalinówka" shows several patterns (Fig. 17). Through the most part of the day, highest air humidity is characteristic for measurements taken at station "Kalinówka" (this correlation is particularly visible in the cold half-year). At dawn and during the night air humidity at the Dam increases in comparison to the other stations. In the hours between 9–17 UTC, high similarity between the course of air humidity at stations "Zapora" and "Tarnówek" is observed. The phase of humidity increase is longer than the decrease phase, and the highest daily amplitude of air humidity is observed at the station with the lowest surface albedo – "Zapora".

On the other hand, the daily course of air temperature changes at three measurement stations installed within the zone of influence of „Żelazny Most" shows that the lowest air temperature in the morning and at noon is measured at the station located on the embankment crown – „Zapora". Evening measurements show that the pond begins to emit the heat collected during the day, which causes an increase in air temperature on the „Zapora" in comparison to the remaining measurement sites. Evening measurements confirm the existence of the phenomenon consisting in the flow of cool air into lower areas of the land (Fig. 18). The correlation between the increase in air humidity and decrease in air temperature is particularly noticeable in the morning and at night. In the warm half-year the differences between the conditions at the analysed stations are less manifested, particularly during daytime.

The analysis of temporary wind speed on the selected days confirms the hypothesis that wind speed increases as a result of the elevation and low roughness of the surface of „Żelazny Most". Basing on data from the cool period it was found that wind speed measured at station „Tarnówek" was the lowest of all analysed values. This specific property is less visible in the measurements from the warm period. The correlation between wind speed and air humidity should be emphasized. Air humidity at the analysed stations decreases along with the increase in wind speed. The measurements show that there are moments of calm at the „Zapora" station, although they occur only rarely. The course of temporary wind speed on the discussed days is presented in Figure 19.

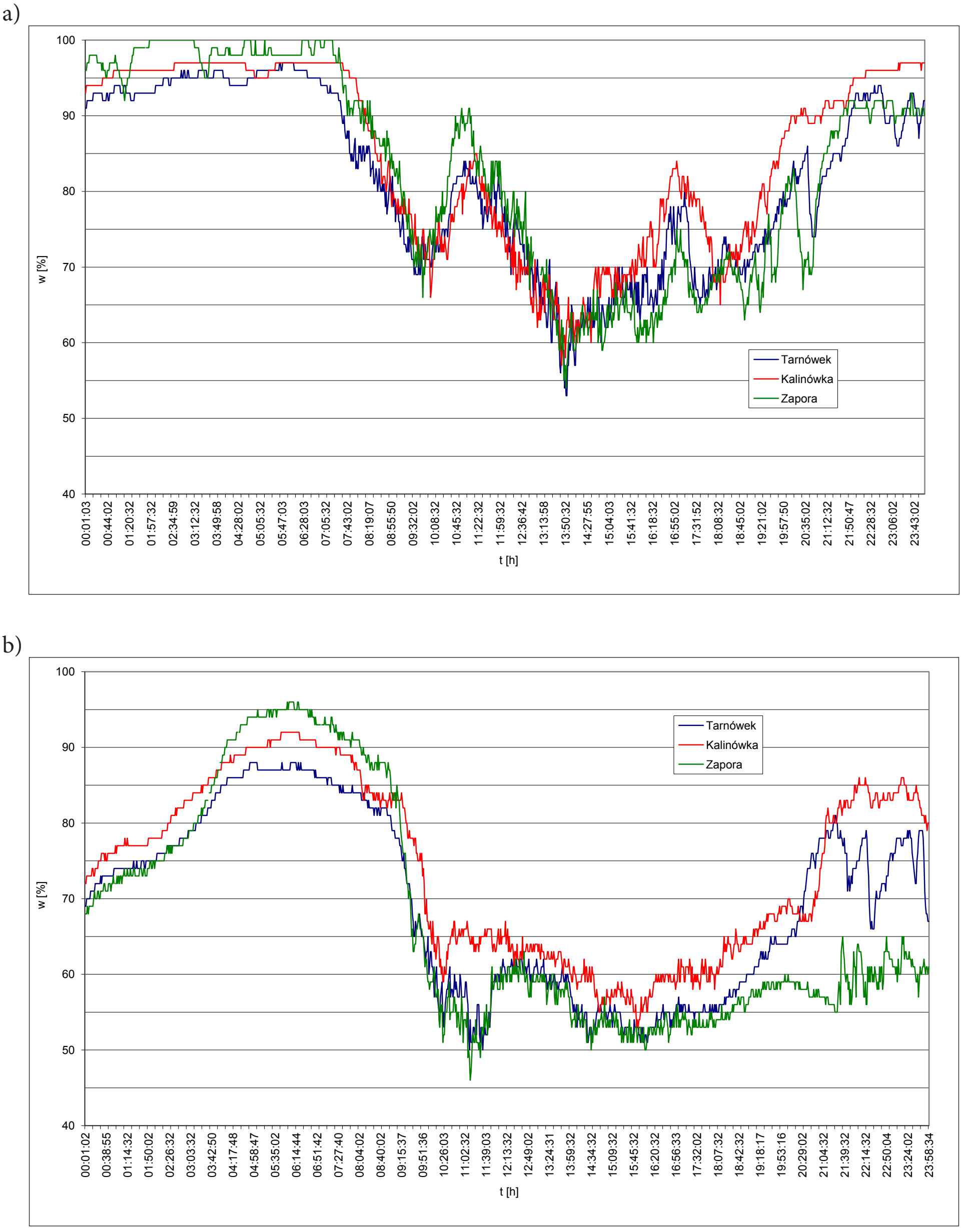


Fig. 17. Course of temporary air humidity [%] at stations "Tarnówek", "Zapora", "Kalinówka":
a) 02.07.2009, b) 20.03.2009

Rys. 17. Przebieg chwilowej wilgotności powietrza [%] na stacjach "Tarnówek", "Zapora", "Kalinówka":
a) 02.07.2009 r., b) 20.03.2009 r.

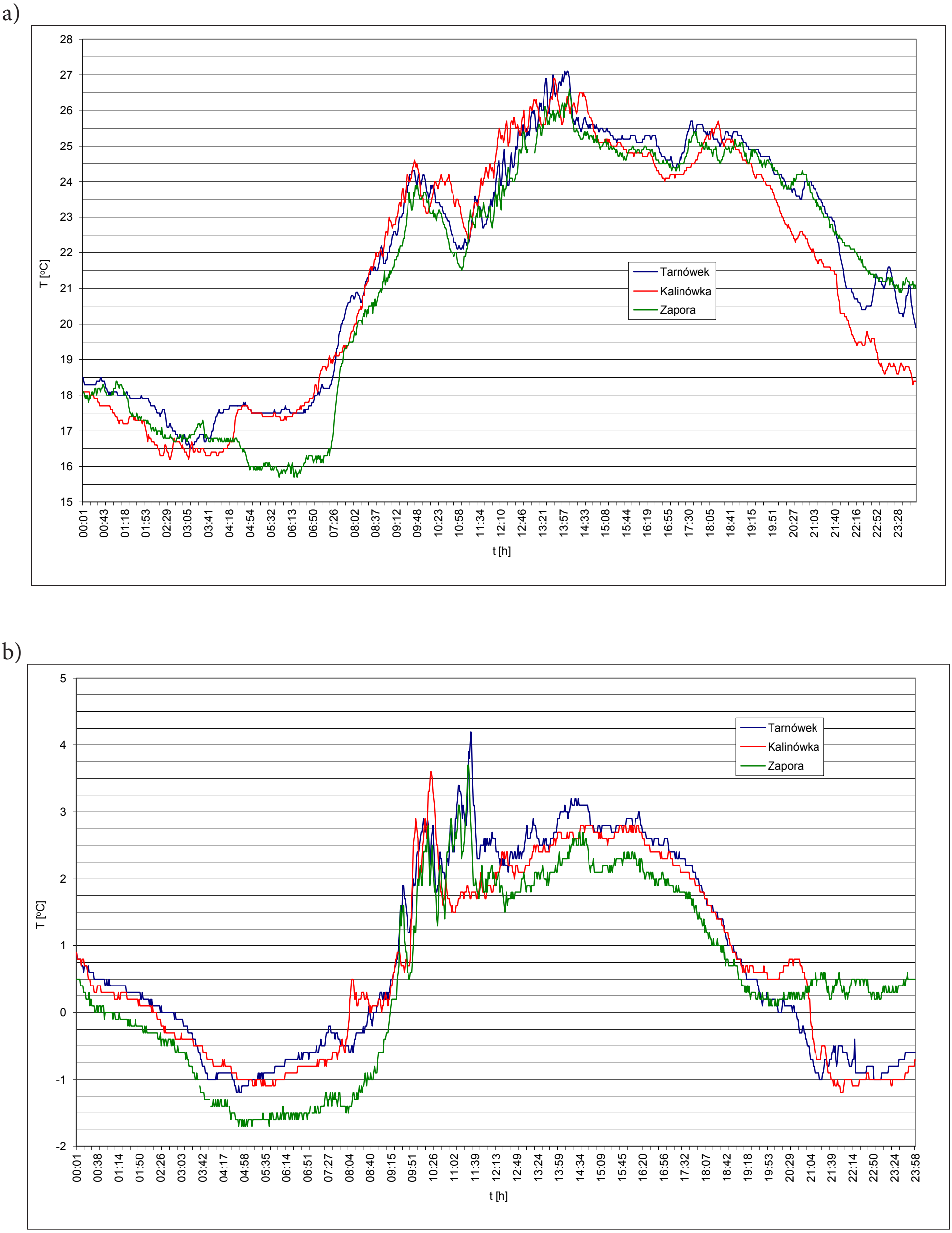


Fig. 18. Course of temporary air temperature [°C] at stations "Tarnówek", "Zapora", "Kalinówka":
a) 02.07.2009, b) 20.03.2009
Rys. 18. Przebieg chwilowej temperatury powietrza [°C] na stacjach "Tarnówek", "Zapora", "Kalinówka":
a) 02.07.2009 r., b) 20.03.2009 r.

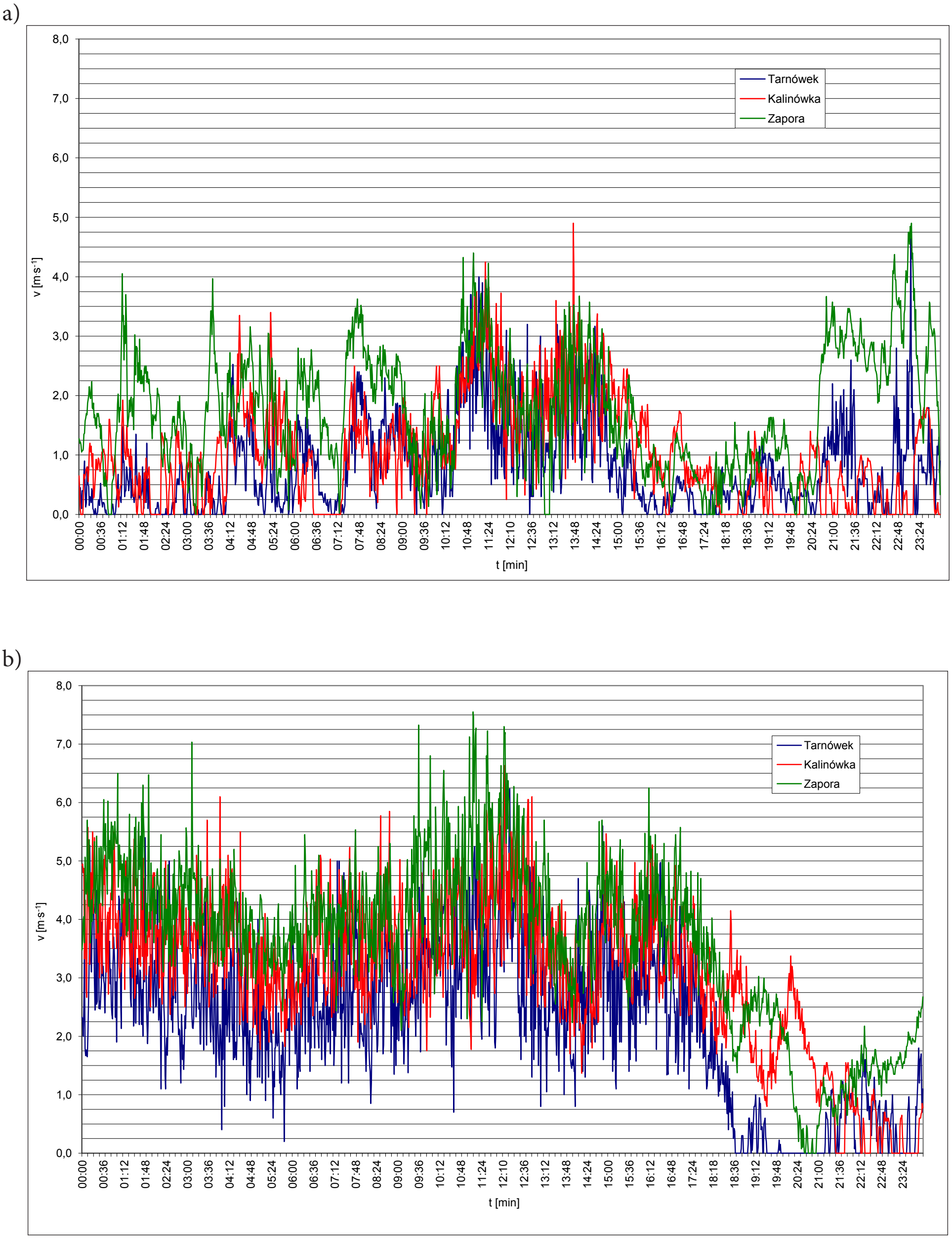


Fig. 19. Course of temporary wind speed [m·s^{-1}] at stations "Tarnówek", "Zapora", "Kalinówka":
a) 02.07.2009, b) 20.03.2009
Rys. 19. Przebieg chwilowej prędkości wiatru [m·s^{-1}] na stacjach "Tarnówek", "Zapora", "Kalinówka":
a) 02.07.2009 r., b) 20.03.2009 r.

6.5. DIFFERENCE SIGNIFICANCE TEST

The present dissertation includes tests of the significance of differences between the conditions measured at individual meteorological stations in order to confirm the actual existence of differentiation.

Prior to testing the significance of differences the data distribution was analysed with use of the W Shapiro-Wilk tests, supplemented by the chi square test. The W Shapiro-Wilk test is one of the most popular normality tests although it can sometimes yield incorrect results for samples consisting of more than two thousand cases [Stanisz 2006]. Two hypotheses were assumed for the purpose of the tests:

H0 – the distribution of the given variable is a normal distribution,

H1 – the distribution of the given variable is not a normal distribution.

Normal distribution occurs when the density function of random variable X characterized by parameters m and σ is expressed by the following formula:

$$f(x) = \frac{1}{\sigma\sqrt{2\Pi}} e^{-\frac{(x-m)^2}{2\sigma^2}} \quad , -\infty < x < \infty \qquad (5)$$

where m and σ are distribution parameters (mean value and standard deviation) [Pruchnicki 1987, Stanisz 2006].

Two hypotheses are assumed for the purposes of the test of significance of differences:
H0 – that the Tailing Pond does not influence the analysed elements of climate (the results of the compared observations have similar distribution),
H1 – that the influence of the TP on the analysed meteorological elements really exists (there are significant differences between the distribution of observations from the compared stations).

The level of significance of the tested hypotheses is considered to be the value $p = 0.05$. More information about conclusions based on hypotheses can be found in the works of Bokwa, Urstnul [2004], Kal [2002], Koronacki and Mielniczuk [2006], Ostasiewicz et al. [1999].

The Student's test is usually applied for this purpose, as it enables to determine the differences between the mean values of the samples. However, for the purposes of this study the non-parametric signed rank Wilcoxon test (hereinafter referred to as the Wilcoxon test) was used. This is due to the lack of normality of the analysed data that are at the same time interrelated. The algorithm for the selection of the significance test for related data is presented in Figure 20.

The Wilcoxon's test takes into account the sign of the differences, their size and order. After arranging the differences in form of a series in increasing order they are assigned ranks, and then the ranks of positive and negative differences are totalled. The lower of the obtained sums is the value of Wilcoxon's test, which is then compared with a corresponding theoretical value in the tables. Basing on such comparison, the null hypothesis is either rejected or not. This test is the strongest alternative option for the Student's test for interrelated variables. It is used in all situations when, due to the lack of normality, the Student's test cannot be applied [Koronacki, Mielniczuk 2006, Stanisz 2006].

The subject of the analysis were variables in three forms, respectively for relative air humidity, air temperature and wind speed:

- periodical measurements from the years 2003–2008 (6. 12. 18 UTC),
- hourly values from the year 2005.
- temporary measurements taken during anticyclonic weather on the 02.07.2009 and the 20.03.2009.

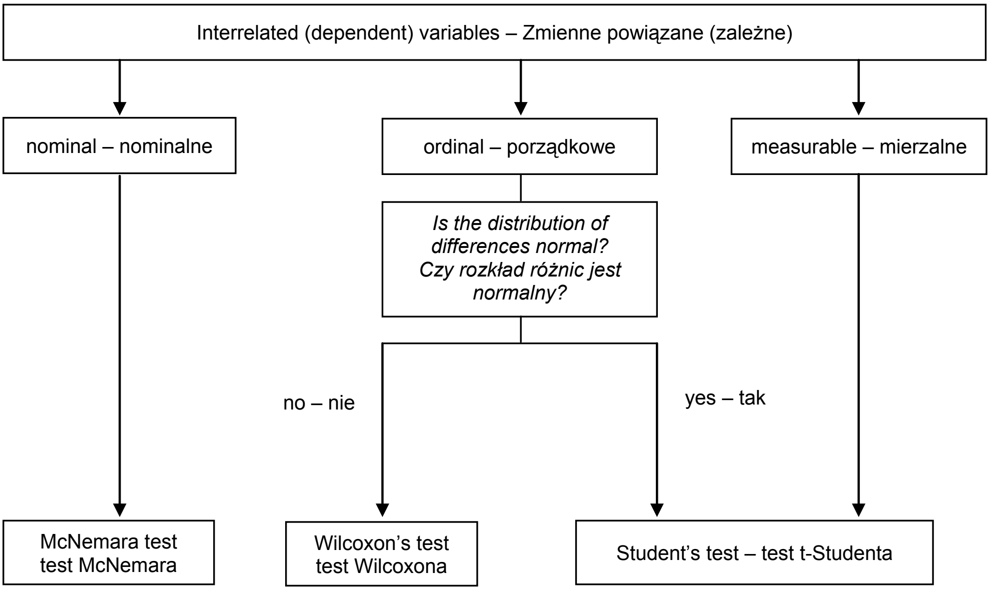


Fig. 20. Algorithm for the selection of the significance test [Stanisz 2006]
Rys. 20. Algorytm doboru testu istotności różnic

The test of normality of the obtained data results in the rejection of the hypothesis about their normality. Due to that, it was decided to test the significance with use of Wilcoxon's test. The results of this test and the diagrams of basic characteristics are presented below in Tables 2–10 and Figures 21–29.

The analysis of data obtained from periodical measurements of relative air humidity from the years 2003–2008 nearly in all cases leads to the rejection of the hypothesis stating that there are no significant differences in the distribution of variables between the conditions on individual stations (the exceptions are the measurements from "Polkowice" and "Tarnówek" at 6 UTC, "Polkowice" and "Kalinówka" at 12 UTC and "Polkowice" and "Zapora" at 18 UTC).

On the other hand the test conducted on mean hourly values of relative air humidity from the year 2005 does not show any significant differences in the humidity conditions between the following stations: "Polkowice" and "Tarnówek", "Polkowice" and "Zapora", "Tarnówek" and "Zapora", "Zapora" and "Kalinówka" and "Zapora" and "Rudna". However, the differences are considered significant in the cases of measurements from points: "Polkowice" and "Kalinówka", "Polkowice" and "Rudna", "Tarnówek" and "Kalinówka" and "Tarnówek" and "Rudna".

The test of significance of differences for temporary data confirms the differences between the humidity conditions on stations located within the predicted zone of influence of the tailing pond.

Table 2
Tabela 2

Chart of Wilcoxon's test results for air humidity [%] in the years 2003–2008 at hours: a) 6 UTC, b) 12 UTC, c) 18 UTC (where: N valid – number of the analysed group, T – value of Wilcoxon's test for groups = < 25, Z – value of Wilcoxon's test for groups n > 25, significance level p – significance level for Wilcoxon's test)
Arkusz wyników testu Wilcoxona dla wilgotności powietrza [%] w latach 2003–2008 z godziny: a) 6 UTC, b) 12 UTC, c) 18 UTC (gdzie: N ważnych – liczebność grup, T – wartość testu Wilcoxona dla grup n = <25, Z – wartość testu Wilcoxona dla grup n > 25, poziom istotności p – poziom istotności dla testu Wilcoxona)

a)

Pair of variables Para zmiennych	Wilcoxon's signed rank test – Test istotności par Wilxona			
	N valid N ważnych	T	Z	significance level p poziom istotności p
Polkowice, Tarnówek	2817	1137366	0.54	0.59
Polkowice, Zapora	2817	450656	24.99	0.00
Polkowice, Kalinówka	2817	1060452	3.46	0.00
Polkowice, Rudna	2817	6063344	17.11	0.00
Tarnówek, Zapora	2817	482228	23.85	0.00
Tarnówek, Kalinówka	2817	911652	8.59	0.00
Tarnówek, Rudna	2817	332268	28.43	0.00
Zapora, Kalinówka	2817	338584	28.92	0.00
Zapora, Rudna	2817	223319	32.74	0.00

b)

Pair of variables Para zmiennych	Wilcoxon's signed rank test – Test istotności par Wilxona			
	N valid N ważnych	T	Z	significance level p poziom istotności p
Polkowice, Tarnówek	2187	1105308	2.87	0.00
Polkowice, Zapora	2187	823661	12.42	0.00
Polkowice, Kalinówka	2187	1181579	0.17	0.87
Polkowice, Rudna	2187	963101	3.92	0.00
Tarnówek, Zapora	2187	352369	28.45	0.00
Tarnówek, Kalinówka	2187	988911	6.44	0.00
Tarnówek, Rudna	2187	913012	9.01	0.00
Zapora, Kalinówka	2187	721548	15.92	0.00
Zapora, Rudna	2187	863729	10.80	0.00

c)

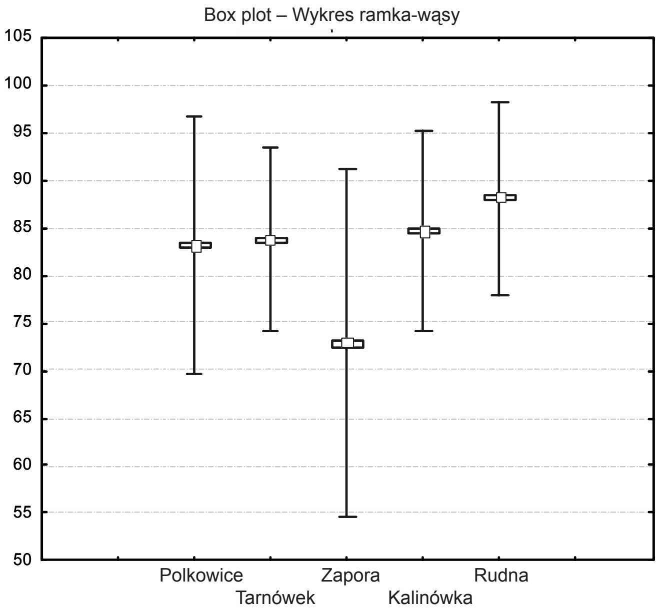
Pair of variables Para zmiennych	Wilcoxon's signed rank test – Test istotności par Wilxona			
	N valid N ważnych	T	Z	significance level p poziom istotności p
Polkowice, Tarnówek	2190	380190	27.43	0.00
Polkowice, Zapora	2190	1147272	1.48	0.14
Polkowice, Kalinówka	2190	514221	22.88	0.00
Polkowice, Rudna	2190	565954	18.87	0.00
Tarnówek, Zapora	2190	419819	26.10	0.00
Tarnówek, Kalinówka	2190	939795	7.99	0.00
Tarnówek, Rudna	2190	681163	16.96	0.00
Zapora, Kalinówka	2190	757047	14.79	0.00
Zapora, Rudna	2190	925713	8.91	0.00

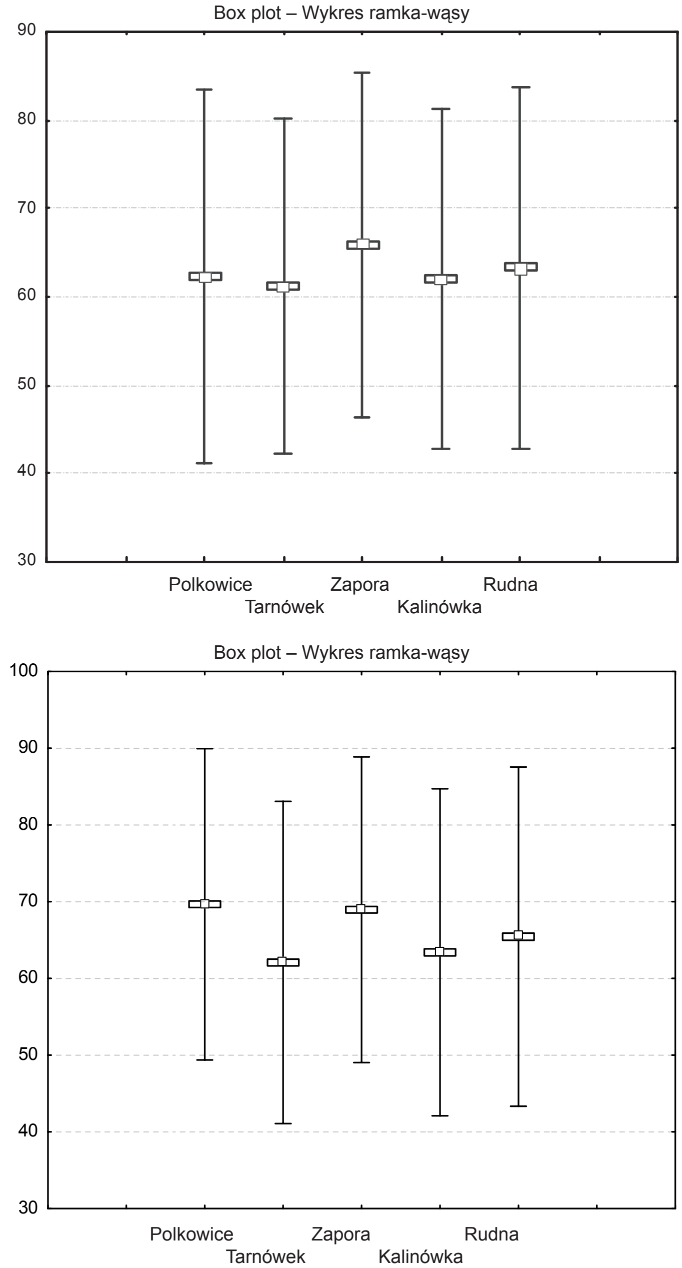
Table 3
Tabela 3

Chart of Wilcoxon's test results for mean hourly values of air humidity [%] in year 2005 (where: N valid – number of the analysed group, T – value of Wilcoxon's test for groups = < 25, Z – value of Wilcoxon's test for groups n > 25, significance level p – significance level for Wilcoxon's test)
Arkusz wyników testu Wilcoxona dla średnich godzinowych wartości wilgotności powietrza [%] w roku 2005 (gdzie: N ważnych – liczebność grup, T – wartość testu Wilcoxona dla grup n = < 25, Z – wartość testu Wilcoxona dla grup n > 25, poziom istotności p – poziom istotności dla testu Wilcoxona

Pair of variables Para zmiennych	Wilcoxon's signed rank test Test istotności par Wilxona			
	N valid N ważnych	T	Z	significance level p poziom istotności p
Polkowice, Tarnówek	24	83	1.91	0.06
Polkowice, Zapora	24	120	0.86	0.39
Polkowice, Kalinówka	24	43	3.06	0.00
Polkowice, Rudna	24	65	2.43	0.02
Tarnówek, Zapora	24	134	0.46	0.65
Tarnówek, Kalinówka	24	0	4.29	0.00
Tarnówek, Rudna	24	5	4.14	0.00
Zapora, Kalinówka	24	147	0.09	0.93
Zapora, Rudna	24	95	1.57	0.12

a)





b)

c)

□ arthmetic mean – średnia

▯ arthmetic mean + standard error – średnia + błąd standardowy

⌶ arthmetic mean + standard deviation – odchylenie standardowe

Fig. 21. Box plot of air humidity [%] in the years 2003–2008 at hours: a) 6 UTC, b) 12 UTC, c) 18 UTC [legenda: arithmetic mean; arithmetic mean + standard error; arithmetic mean + standard deviation]
Rys. 21. Wykres ramka-wąsy dla wilgotności powietrza [%] w latach 2003–2008 z godziny: a) 6 UTC, b) 12 UTC, c) 18 UTC

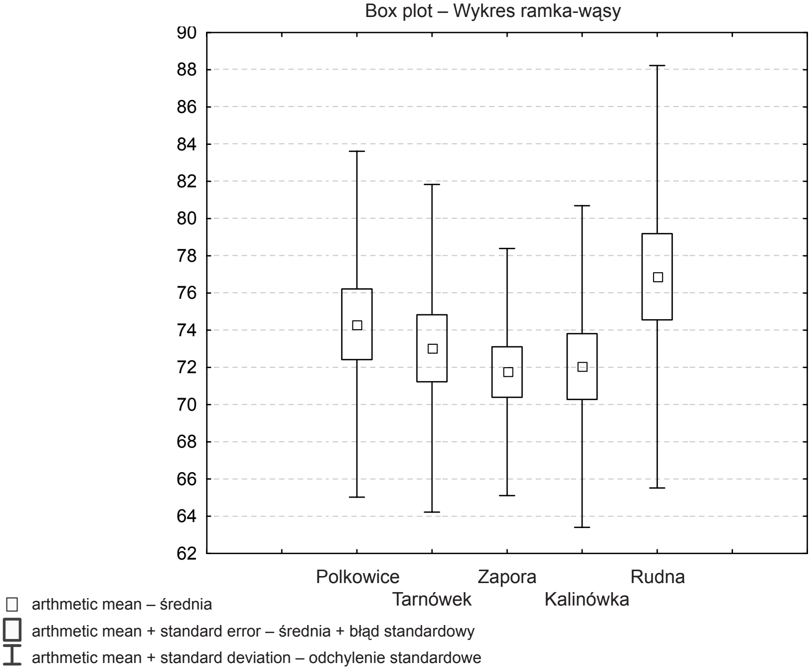


Fig. 22. Box plot of mean hourly air humidity [%] in year 2005 at individual stations
Rys. 22. Wykres ramka-wąsy średniej godzinowej wilgotności powietrza [%] w roku 2005 na poszczególnych stacjach

Table 4
Tabela 4

Chart of Wilcoxon's test results for temporary values of air humidity [%]: a) 02.07.2009, b) 20.03.2009 (where: N valid – number of the analysed group, T – value of Wilcoxon's test for groups = < 25, Z – value of Wilcoxon's test for groups n >25, significance level p – significance level for Wilcoxon's test)
Arkusz wyników testu Wilcoxona dla chwilowych wartości wilgotności powietrza [%]: a) 02.07.2009 r., b) 20.03.2009 r. (gdzie: N ważnych – liczebność grup, T – wartość testu Wilcoxona dla grup n = < 25, Z – wartość testu Wilcoxona dla grup n > 25, poziom istotności p – poziom istotności dla testu Wilcoxona)

a)

Pair of variables Para zmiennych	Wilcoxon's signed rank test – Test istotności par Wilxona			
	N valid N ważnych	T	Z	significance level p poziom istotności p
Tarnówek, Zapora	1010	144062	11.99	0.00
Tarnówek, Kalinówka	1010	59159	21.15	0.00
Zapora, Kalinówka	1010	197346	6.87	0.00

b)

Pair of variables Para zmiennych	Wilcoxon's signed rank test – Test istotności par Wilxona			
	N valid N ważnych	T	Z	significance level p poziom istotności p
Tarnówek, Zapora	1061	17668	26.45	0.00
Tarnówek, Kalinówka	1061	168689	6.80	0.00
Zapora, Kalinówka	1061	55818	22.65	0.00

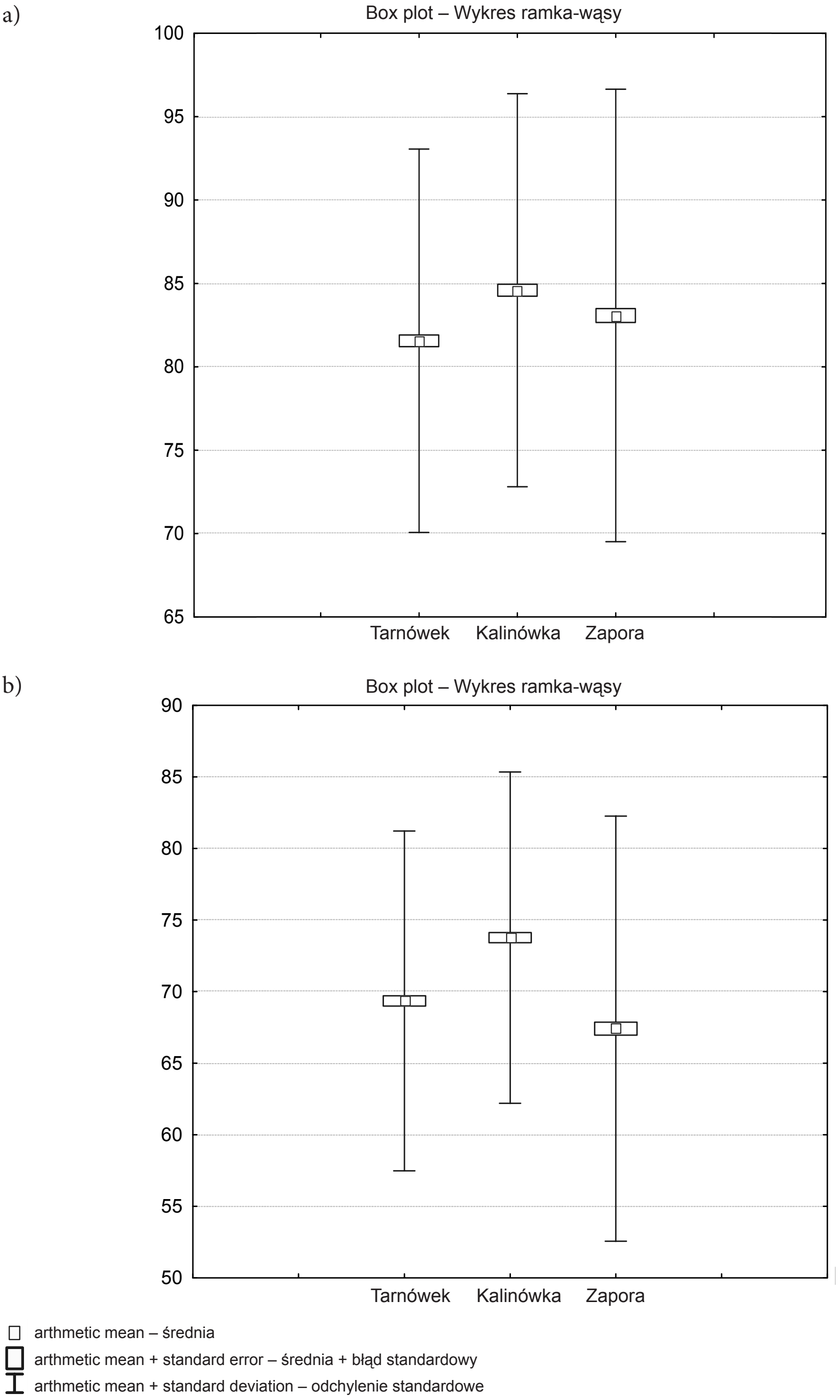


Fig. 23. Box plot of temporary air humidity [%]: a) 02.07.2009, b) 20.03.2009
Rys. 23. Wykres ramka-wąsy chwilowej wilgotności powietrza [%]:
a) 02.07.2009 r., b) 20.03.2009 r.

Table 5

Tabela 5

Chart of Wilcoxon's test results for mean hourly values of air temperature [°C] in the years 2003–2008 at hours: a) 6 UTC, b) 12 UTC, c) 18 UTC (where: N valid – number of the analysed group, T – value of Wilcoxon's test for groups = < 25, Z – value of Wilcoxon's test for groups n >25, significance level p – significance level for Wilcoxon's test)

Arkusz wyników testu Wilcoxona dla temperatury powietrza [°C] w latach 2003–2008 o godzinie: a) 6 UTC, b) 12 UTC, c) 18 UTC (gdzie: N ważnych – liczebność grup, T – wartość testu Wilcoxona dla grup n = < 25, Z – wartość testu Wilcoxona dla grup n > 25, poziom istotności p – poziom istotności dla testu Wilcoxona)

a)

Pair of variables Para zmiennych	Wilcoxon's signed rank test – Test istotności par Wilxona			
	N valid N ważnych	T	Z	significance level p poziom istotności p
Polkowice, Tarnówek	2181	606570	19.73	0.00
Polkowice, Zapora	2181	766776	14.35	0.00
Polkowice, Kalinówka	2181	610667	19.62	0.00
Polkowice, Rudna	2181	720071	14.91	0.00
Tarnówek, Zapora	2181	920886	9.11	0.00
Tarnówek, Kalinówka	2181	1150379	1.05	0.29
Tarnówek, Rudna	2181	902039	9.75	0.00
Zapora, Kalinówka	2181	891667	10.01	0.00
Zapora, Rudna	2181	1143933	1.56	0.12

b)

Pair of variables Para zmiennych	Wilcoxon's signed rank test – Test istotności par Wilxona			
	N valid N ważnych	T	Z	significance level p poziom istotności p
Polkowice, Tarnówek	2187	1034259	5.42	0.00
Polkowice, Zapora	2187	996163	6.78	0.00
Polkowice, Kalinówka	2187	1141990	1.66	0.10
Polkowice, Rudna	2187	731437	13.32	0.00
Tarnówek, Zapora	2187	379232	27.66	0.00
Tarnówek, Kalinówka	2187	758374	14.72	0.00
Tarnówek, Rudna	2187	677135	17.58	0.00
Zapora, Kalinówka	2187	547436	21.95	0.00
Zapora, Rudna	2187	429074	25.98	0.00

c)

Pair of variables Para zmiennych	Wilcoxon's signed rank test – Test istotności par Wilxona			
	N valid N ważnych	T	Z	significance level p poziom istotności p
Polkowice, Tarnówek	2187	540339	22.17	0.00
Polkowice, Zapora	2187	487281	24.01	0.00
Polkowice, Kalinówka	2187	500811	23.53	0.00
Polkowice, Rudna	2187	476969	23.84	0.00
Tarnówek, Zapora	2187	1122694	2.46	0.01
Tarnówek, Kalinówka	2187	939197	7.99	0.00
Tarnówek, Rudna	2187	830712	12.38	0.00
Zapora, Kalinówka	2187	1111822	2.82	0.00
Zapora, Rudna	2187	991378	6.91	0.00

Table 6
Tabela 6

Chart of Wilcoxon's test results for mean hourly values of air temperature [°C] in the year 2005 (where: N valid – number of the analysed group, T – value of Wilcoxon's test for groups = < 25, Z – value of Wilcoxon's test for groups n > 25, significance level p – significance level for Wilcoxon's test)
Arkusz wyników testu Wilcoxona dla średnich godzinowych wartości temperatury powietrza [°C] w roku 2005 (gdzie: N ważnych – liczebność grup, T – wartość testu Wilcoxona dla grup n = < 25, Z – wartość testu Wilcoxona dla grup n > 25, poziom istotności p – poziom istotności dla testu Wilcoxona)

Pair of variables Para zmiennych	Wilcoxon's signed rank test – Test istotności par Wilxona			
	N valid N ważnych	T	Z	significance level p poziom istotności p
Polkowice, Tarnówek	24	134	0.46	0.65
Polkowice, Zapora	24	138	0.34	0.73
Polkowice, Kalinówka	24	122	0.80	0.42
Polkowice, Rudna	24	69	2.31	0.02
Tarnówek, Zapora	24	77	2.09	0.04
Tarnówek, Kalinówka	24	132	0.51	0.61
Tarnówek, Rudna	24	65	2.43	0.02
Zapora, Kalinówka	24	72	2.23	0.03
Zapora, Rudna	24	73	2.20	0.03

Table 7
Tabela 7

Chart of Wilcoxon's test results for temporary values of air temperature [°C]: a) 02.07.2009, b) 20.03.2009 (where: N valid – number of the analysed group, T – value of Wilcoxon's test for groups = < 25, Z – value of Wilcoxon's test for groups n > 25, significance level p – significance level for Wilcoxon's test)
Arkusz wyników testu Wilcoxona dla chwilowych wartości temperatury powietrza [°C]: a) 02.07.2009 r., b) 20.03.2009 r. (gdzie: N ważnych – liczebność grup, T – wartość testu Wilcoxona dla grup n = < 25, Z – wartość testu Wilcoxona dla grup n > 25, poziom istotności p – poziom istotności dla testu Wilcoxona)

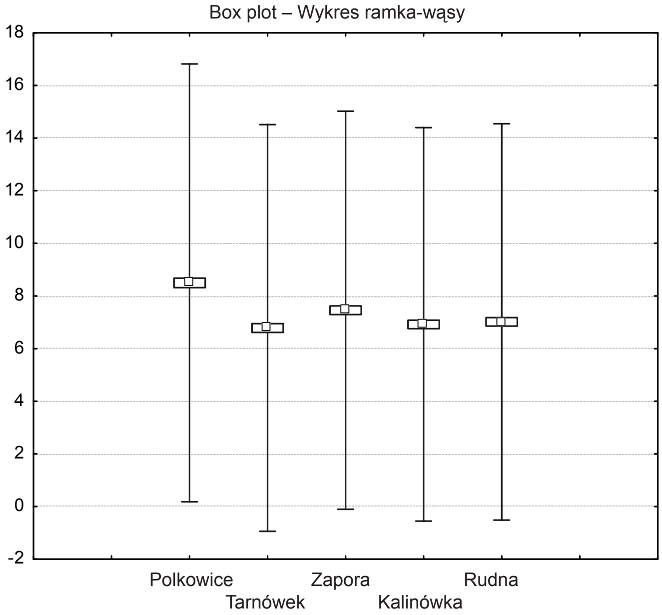
a)

Pair of variables Para zmiennych	Wilcoxon's signed rank test – Test istotności par Wilxona			
	N valid N ważnych	T	Z	significance level p poziom istotności p
Tarnówek, Zapora	1015	117711	15.00	0.00
Tarnówek, Kalinówka	1015	78362	19.26	0.00
Zapora, Kalinówka	1015	250723	1.29	0.20

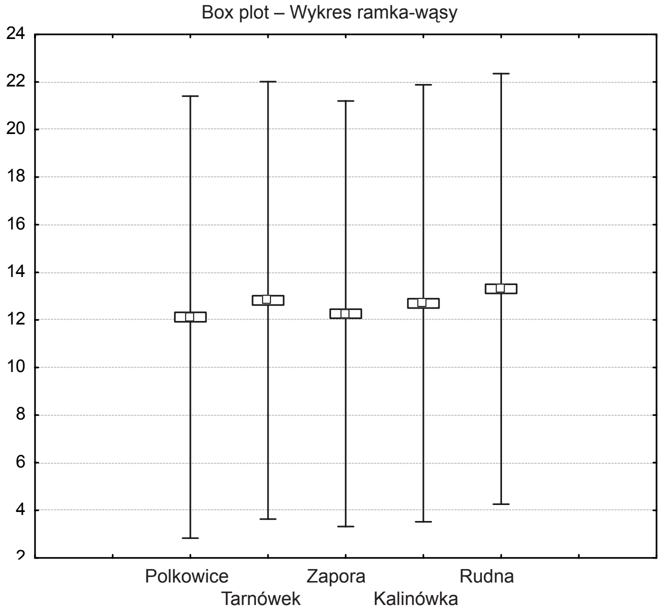
b)

Pair of variables Para zmiennych	Wilcoxon's signed rank test – Test istotności par Wilxona			
	N valid N ważnych	T	Z	significance level p poziom istotności p
Tarnówek, Zapora	1053	134595	10.55	0.00
Tarnówek, Kalinówka	1053	140350	13.89	0.00
Zapora, Kalinówka	1053	165126	11.60	0.00

a)


Box plot – Wykres ramka-wąsy
18
16
14
12
10
8
6
4
2
0
-2
Polkowice
Tarnówek
Zapora
Kalinówka
Rudna

b)


Box plot – Wykres ramka-wąsy
24
22
20
18
16
14
12
10
8
6
4
2
Polkowice
Tarnówek
Zapora
Kalinówka
Rudna

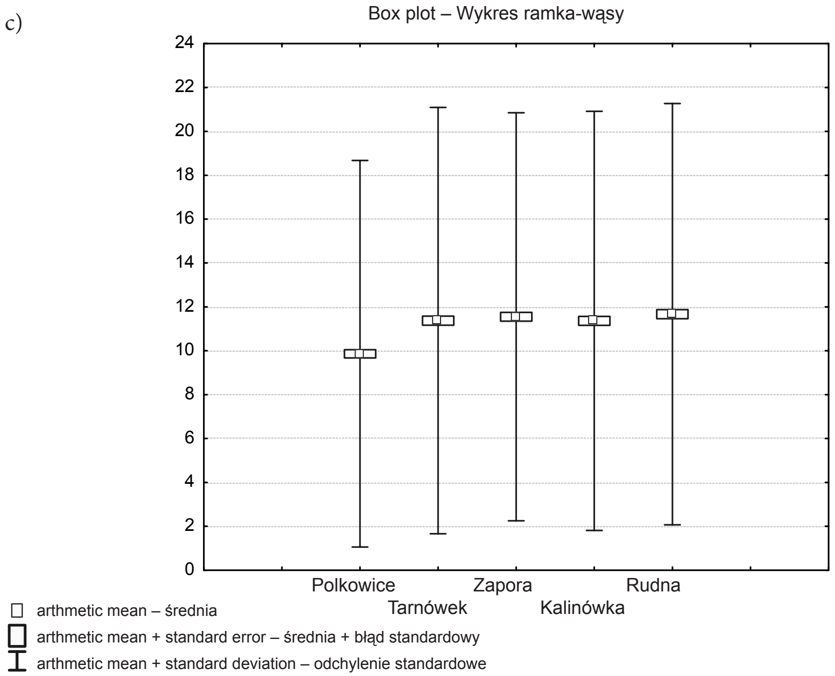


Fig. 24. Box-plot diagram of air temperature [°C] in the years 2003–2008 at hours: a) 6 UTC, b) 12 UTC, c) 18 UTC

Rys. 24. Wykres ramka-wąsy dla temperatury powietrza [°C] w latach 2003–2008 o godzinie: a) 6 UTC, b) 12 UTC, c) 18 UTC

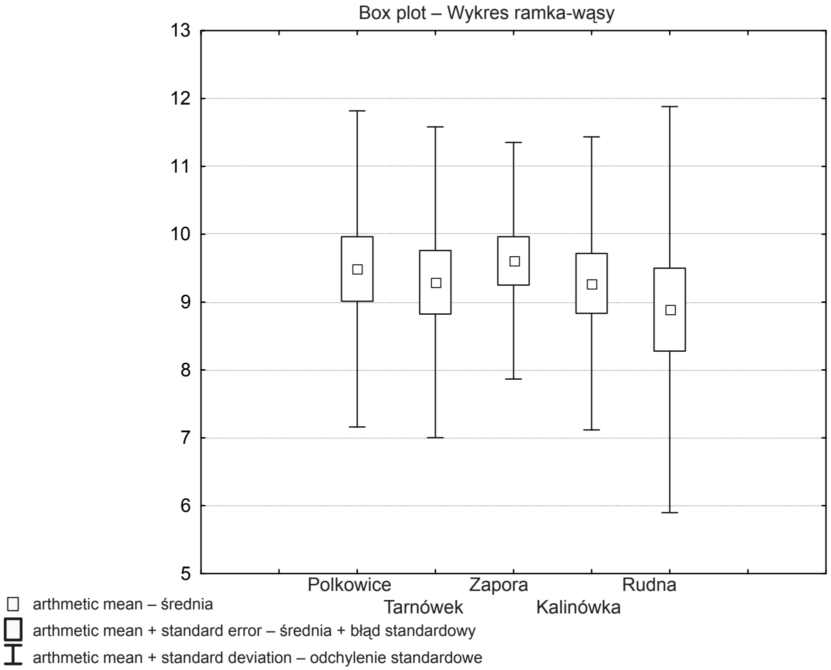


Fig. 25 Box-plot diagram of mean hourly air temperature [°C] in the year 2005

Rys. 25. Wykres ramka-wąsy średniej godzinowej temperatury powietrza [°C] w roku 2005

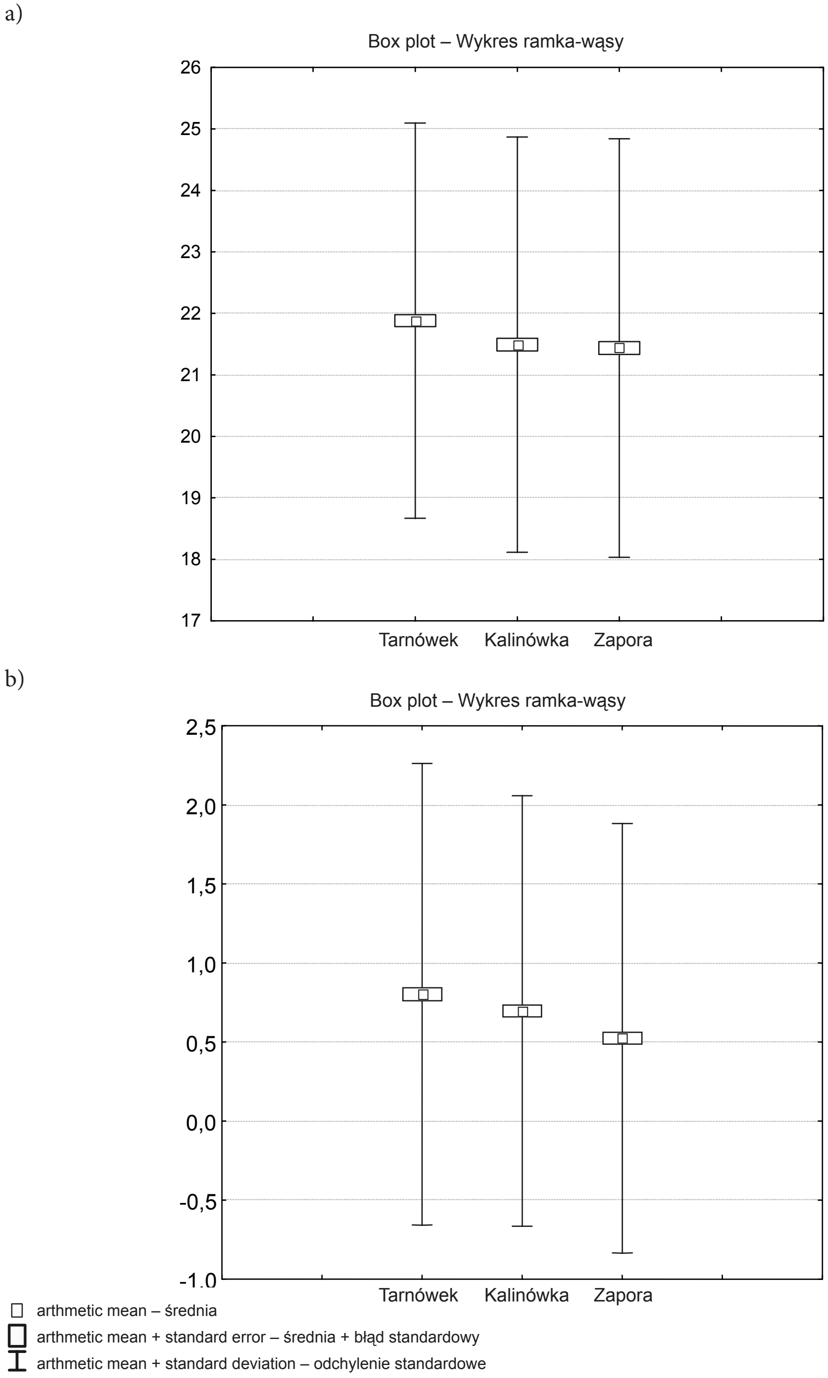


Fig. 26. Box-plot diagram of mean temporary values of air temperature [°C]: a) 02.07.2009, b) 20.03.2009
Rys. 26. Wykres ramka-wąsy średniej chwilowej temperatury powietrza [°C]: a) 02.07.2009 r., b) 20.03.2009 r.

Table 8

Tabela 8

Chart of Wilcoxon's test results for wind speed [m·s^{-1}] in the years 2003–2008 at hours: a) 6 UTC, b) 12 UTC, c) 18 UTC (where: N valid – number of the analysed group, T – value of Wilcoxon's test for groups = < 25, Z – value of Wilcoxon's test for groups n > 25, significance level p – significance level for Wilcoxon's test)

Arkusz wyników testu Wilcoxona dla prędkości wiatru [m·s^{-1}] w latach 2003–2008 o godzinie: a) 6 UTC, b) 12 UTC, c) 18 UTC (gdzie: N ważnych – liczebność grup, T – wartość testu Wilcoxona dla grup n = < 25, Z – wartość testu Wilcoxona dla grup n > 25, poziom istotności p – poziom istotności dla testu Wilcoxona)

a)

Pair of variables Para zmiennych	Wilcoxon's signed rank test – Test istotności par Wilxona			
	N valid N ważnych	T	Z	significance level p poziom istotności p
Polkowice, Tarnówek	2089	1058084	0.62	0.54
Polkowice, Zapora	2089	296915	28.78	0.00
Polkowice, Kalinówka	2089	1027774	1.43	0.15
Polkowice, Rudna	2089	953836	1.62	0.11
Tarnówek, Zapora	2089	102294	35.83	0.00
Tarnówek, Kalinówka	2089	954946	4.64	0.00
Tarnówek, Rudna	2089	1063037	0.05	0.96
Zapora, Kalinówka	2089	212536	31.86	0.00
Zapora, Rudna	2089	172951	33.27	0.00

b)

Pair of variables Para zmiennych	Wilcoxon's signed rank test – Test istotności par Wilxona			
	N valid N ważnych	T	Z	significance level p poziom istotności p
Polkowice, Tarnówek	2101	881342	8.01	0.00
Polkowice, Zapora	2101	150720	34.28	0.00
Polkowice, Kalinówka	2101	661484	15.89	0.00
Polkowice, Rudna	2101	7617667	10.68	0.00
Tarnówek, Zapora	2101	204127	32.36	0.00
Tarnówek, Kalinówka	2101	787990	11.37	0.00
Tarnówek and Rudna	2101	975192	4.36	0.00
Zapora and Kalinówka	2101	288365	29.33	0.00
Zapora and Rudna	2101	266116	30.13	0.00

c)

Pair of variables Para zmiennych	Wilcoxon's signed rank test – Test istotności par Wilxona			
	N valid N ważnych	T	Z	significance level p poziom istotności p
Polkowice, Tarnówek	2099	788222	11.21	0.00
Polkowice, Zapora	2099	127903	35.04	0.00
Polkowice, Kalinówka	2099	555086	19.57	0.00
Polkowice, Rudna	2099	636293	14.52	0.00
Tarnówek, Zapora	2099	124801	35.17	0.00
Tarnówek, Kalinówka	2099	885952	7.75	0.00
Tarnówek, Rudna	2099	863961	8.48	0.00
Zapora, Kalinówka	2099	25008	30.68	0.00
Zapora, Rudna	2099	215355	31.88	0.00

The test of significance of differences for air temperature measurements at the main measurement hours from the multi-annual period confirms the hypothesis that the distribution of variables differs nearly in all cases. Exceptions are the pairs of observations from stations "Tarnówek" and "Kalinówka", "Zapora" and "Rudna" at 6 hours UTC and "Polkowice" and "Kalinówka" at 12 hours UTC.

On the other hand, the test conducted basing on mean hourly values of air temperature constitutes a basis for the elimination of the hypothesis about the differentiation of data distribution in the case of observations taken at stations: „Polkowice" and „Tarnówek", „Polkowice" and „Zapora", „Polkowice" and „Kalinówka", „Tarnówek" and „Zapora", „Tarnówek" and „Kalinówka", „Tarnówek" and „Rudna", „Zapora" and „Kalinówka" and, finally, „Zapora" and „Rudna".

In the case of temporary values of air temperature only measurements taken at stations „Zapora" and „Kalinówka" on the 02.07.2009 do not show any significant differences. The remaining observations confirm the existence of significant differences.

The Wilcoxon's test of significance of differences shows that in the case of wind speed the null hypothesis about the lack of differences between the distribution of analysed pairs of variables was confirmed only for the data obtained from measurements at 6 hours UTC during the period 2003–2008 at stations: „Polkowice" and „Tarnówek", „Polkowice" and „Kalinówka", „Polkowice" and „Rudna" and, finally, „Tarnówek" and „Rudna". In the remaining cases the differences caused by the influence of „Żelazny Most" are significant.

Table 9
Tabela 9

Chart of Wilcoxon's test results for mean hourly values of wind speed [$m \cdot s^{-1}$] in the year 2005 (where: N valid – number of the analysed group, T – value of Wilcoxon's test for groups = < 25, Z – value of Wilcoxon's test for groups n > 25, significance level p – significance level for Wilcoxon's test)

Arkusz wyników testu Wilcoxona dla średnich godzinowych wartości prędkości wiatru [$m \cdot s^{-1}$] w roku 2005 (gdzie: N ważnych – liczebność grup, T - wartość testu Wilcoxona dla grup n = < 25, Z – wartość testu Wilcoxona dla grup n > 25, poziom istotności p – poziom istotności dla testu Wilcoxona)

Pair of variables Para zmiennych	Wilcoxon's signed rank test – Test istotności par Wilxona			
	N valid N ważnych	T	Z	significance level p poziom istotności p
Polkowice, Tarnówek	24	0	4.29	0.00
Polkowice, Zapora	24	0	4.29	0.00
Polkowice, Kalinówka	24	21	3.69	0.00
Polkowice, Rudna	24	22	3.66	0.00
Tarnówek, Zapora	24	0	4.29	0.00
Tarnówek, Kalinówka	24	35	3.29	0.00
Tarnówek, Rudna	24	22	3.66	0.00
Zapora, Kalinówka	24	0	4.29	0.00
Zapora and Rudna	24	0	4.29	0.00

Table 10
Tabela 10

Chart of Wilcoxon's test results for temporary values wind speed [$m \cdot s^{-1}$]: a) 02.07.2009, b) 20.03.2009 (where: N valid – number of the analysed group, T – value of Wilcoxon's test for groups = <25, Z – value of Wilcoxon's test for groups n >25, significance level p – significance level for Wilcoxon's test)
Arkusz wyników testu Wilcoxona dla chwilowych wartości prędkości wiatru [$m \cdot s^{-1}$]: a) 02.07.2009 r., b) 20.03.2009 r. (gdzie: N ważnych – liczebność grup, T – wartość testu Wilcoxona dla grup n = < 25, Z – wartość testu Wilcoxona dla grup n > 25, poziom istotności p – poziom istotności dla testu Wilcoxona)

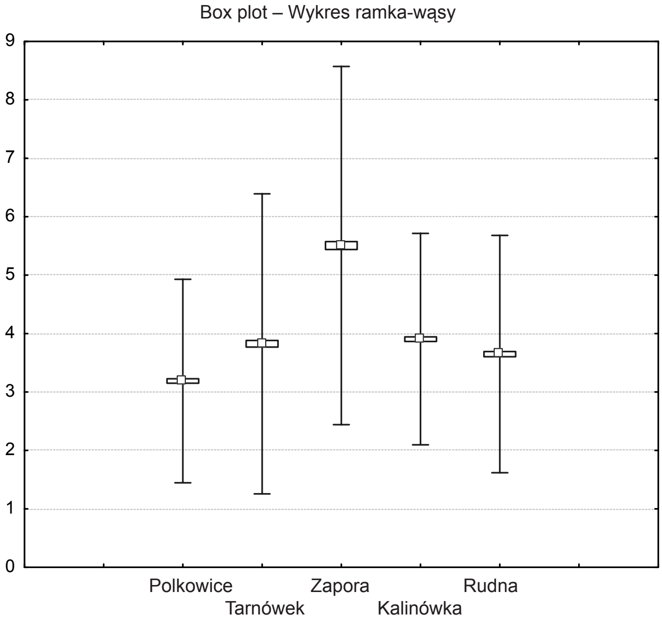
a)

Pair of variables Para zmiennych	Wilcoxon's signed rank test Test istotności par Wilxona			
	N valid N ważnych	T	Z	significance level p poziom istotności p
Tarnówek, Zapora	1041	118208	15.77	0.00
Tarnówek, Kalinówka	1057	28640	25.28	0.00
Zapora, Kalinówka	1061	141650	14.03	0.00

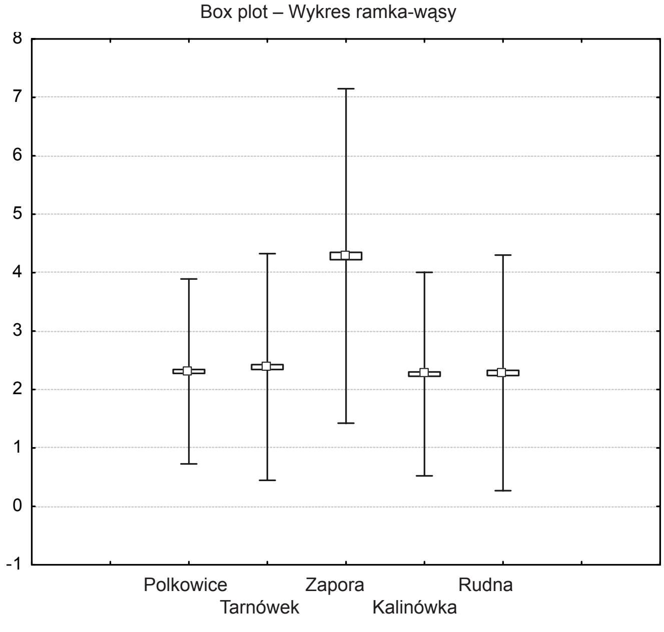
b)

Pair of variables Para zmiennych	Wilcoxon's signed rank test Test istotności par Wilxona			
	N valid N ważnych	T	Z	significance level p poziom istotności p
Tarnówek, Zapora	1073	99912	18.53	0.00
Tarnówek, Kalinówka	1075	19029	26.53	0.00
Zapora, Kalinówka	1071	102798	18.20	0.00

a)


Box plot – Wykres ramka-wąsy
9
8
7
6
5
4
3
2
1
0
Polkowice
Tarnówek
Zapora
Kalinówka
Rudna

b)


Box plot – Wykres ramka-wąsy
8
7
6
5
4
3
2
1
0
-1
Polkowice
Tarnówek
Zapora
Kalinówka
Rudna

c)

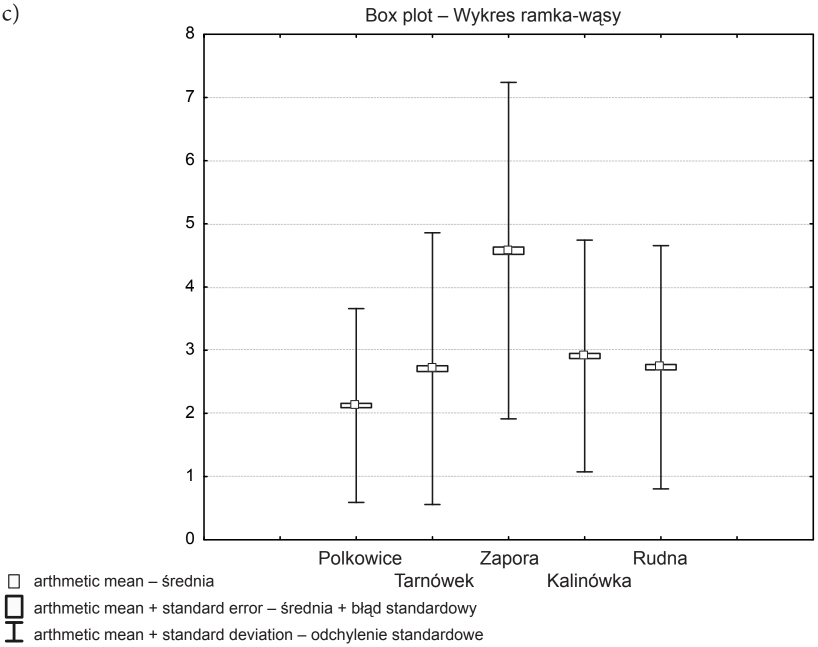


Fig. 27. Box-plot diagram of wind speed [m·s^{-1}] in the years 2003–2008 at hours:
a) 6 UTC, b) 12 UTC, c) 18 UTC
Rys. 27. Wykres ramka-wąsy dla prędkości wiatru [m·s^{-1}] w latach 2003–2008 o godzinie:
a) 6 UTC, b) 12 UTC, c) 18 UTC

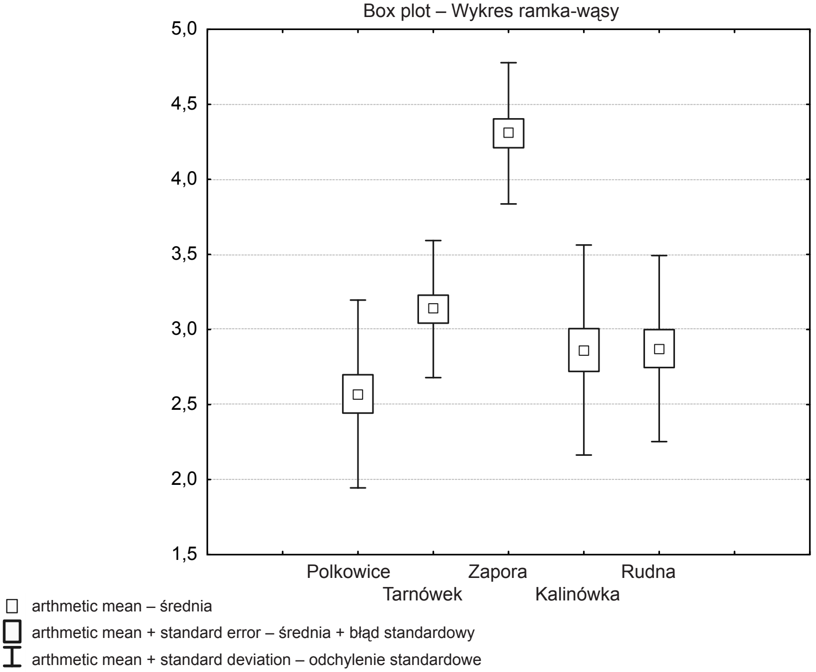


Fig. 28. Box-plot diagram of mean hourly values of wind speed [m·s^{-1}] in year 2005
Rys. 28. Wykres ramka-wąsy średniej godzinowej prędkości wiatru [m·s^{-1}] w roku 2005

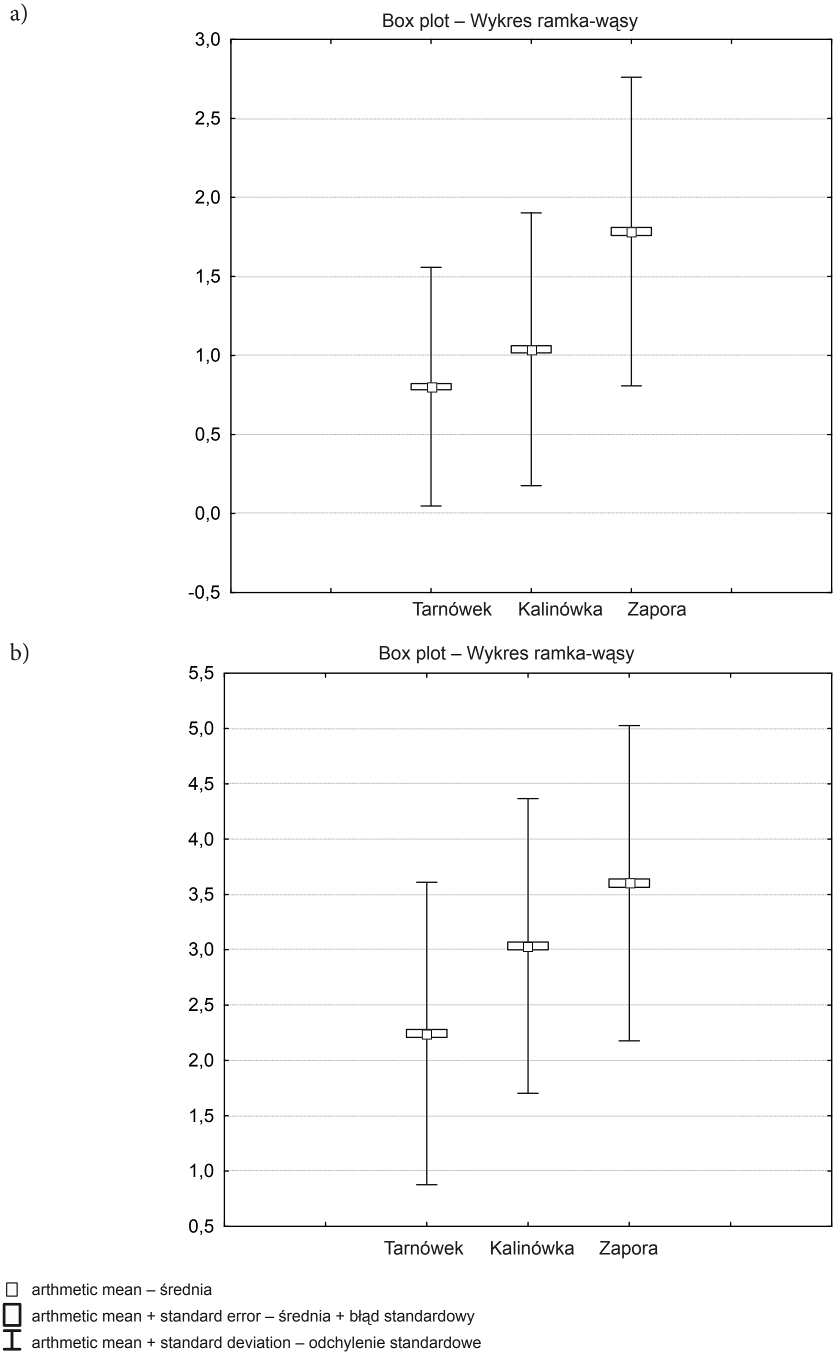


Fig. 29. Box-plot diagram of mean hourly values of wind speed [$m \cdot s^{-1}$]: a) 02.07.2009, b) 20.03.2009
Rys. 29. Wykres ramka-wąsy średniej godzinowej prędkości wiatru [$m \cdot s^{-1}$]: a) 02.07.2009 r., b) 20.03.2009 r.

7. SUMMARY AND CONCLUSIONS

This study discusses the results of analysis of three meteorological factors in the aspect of their changes caused by the existence and exploitation of the tailing pond "Żelazny Most". The study presents basic climate factors and the mechanisms of their functioning. The analysis was conducted basing on meteorological data collected with use of automated measurement stations.

To conclude, it has been proven that the factor that is subject to the largest extent of transformations as a result of the influence of the tailing pond is wind. The highest degree of modification of wind speed is observed on the surface of "Żelazny Most". Throughout the measurement period a significant increase in wind speed was noted there. The differences between wind conditions at observation sites located at the foot of the TP, and the conditions measured at the station of the Institute of Meteorology and Water Management "Polkowice" are, in most cases, statistically significant, but not as noticeable as in the case of "Zapora" and "Polkowice". The evaluation of the influence of "Żelazny Most" on wind conditions, based on mean monthly value, shows an increase in wind speed at all measurement hours. The highest increase in wind speed on the "Zapora" is observed in the evening (18 hours UTC), whereas the lowest in the morning (6 hours UTC). The maximum difference between mean monthly wind speed at the "Zapora" and in "Polkowice" amounted to 3.2 $m \cdot s^{-1}$ and was observed in August. The analysis of data obtained from measurements taken at 6 hours UTC at measurement stations located in the direct proximity of the tailing pond shows that lower mean monthly values of wind speed occur in "Kalinówka" and in "Rudna" in the months: April, June, July, September and October and at station "Tarnówek" in April and May than at the reference station of the Institute of Meteorology and Water Management "Polkowice". Measurements taken at noon at stations "Tarnówek", "Kalinówka" and "Rudna" prove that the wind conditions in "Tarnówek" and in "Rudna" are characterized by lower mean monthly values of wind speed than "Polkowice" only in April and June, whereas in the remaining months mean monthly wind speed is higher than at the station representing standard conditions (Institute of Meteorology and Water Management in Polkowice). The analysis of mean monthly wind speed measured at hours 18 UTC shows that this value is higher in the zone of influence of "Żelazny Most" that in the area not influenced by the object during the major part of year. The exceptions are the measurements taken in February and March at station "Tarnówek" and in January and October at station "Kalinówka". The analysis proved that the highest mean hourly values of wind speed are characteristic for the conditions of operation represented by "Zapora" station. Throughout the day, the mean hourly speed recorded at this station is higher by at least 1 $m \cdot s^{-1}$, than on the remaining stations. The comparison of wind conditions on measurement sites located in the proximity of the object shows that they differ depending on the location and distance from "Żelazny Most". Higher wind speed is recorded throughout the major part of the day in "Tarnówek", with the exception of hours 11–16 UTC, when higher values are measured in "Kalinówka". In "Rudna" higher mean hourly wind speed is observed at night and in the morning hours from 0 to 6 UTC. The evaluation of the influence of the tailing pond on wind speed was also based on the analysis of frequency of occurrence. Wind speed within the ranges 10–15 $m \cdot s^{-1}$ and over 15 $m \cdot s^{-1}$ was measured most frequently at the "Zapora" station, in comparison with the remaining measurement sites. On the surface of the object practically no atmospheric calms occur. On the other hand, the analysis of frequency of occurrence of wind speed over 4 $m \cdot s^{-1}$ at stations located within the area of influence of the TP shows that the highest probability of occurrence of eolian processes exists on the surface of the studied object (more than 50% observations throughout the year). Such values are most frequently recorded at 12 hours UTC in March, April, September, October and November. Thus, stabilization works on the so-called "beaches" of the object should be conducted first of all during these months.

The analysis of results of air humidity measurements shows a visible decrease in mean monthly air humidity in morning measurements at "Zapora" station, in comparison with the measurement site of the Institute of Meteorology and Water Management in Polkowice. These differences are also noticeable at the remaining stations within the zone of influence of "Żelazny Most" although they are much lower. Lower mean monthly air humidity at 6 hours UTC is observed at stations "Tarnówek" and "Kalinówka" in October, November, December, January, February, March, and in "Rudna" only in January. Through the remaining period the mean monthly air humidity values are higher at stations located within the zone of influence of the studied object ("Tarnówek", "Kalinówka", and "Rudna"). The test results also show that at 12 hours UTC throughout the year the mean monthly air humidity on the surface of the TP is higher than in the area outside its zone of influence. On the other hand, at stations located at the foot of "Żelazny Most" ("Tarnówek" and "Kalinówka") and further towards the village Rudna ("Rudna") from November to March a decrease in air humidity is observed in comparison with the standard conditions. However, the analysis of mean monthly air humidity values obtained at 18 hours UTC points to the fact that the influence of "Żelazny Most" on air humidity on its surface is the weakest at this time of day, and the course of these values throughout the year is the most similar to the course in standard conditions. On the other hand, at stations "Tarnówek", "Kalinówka" and "Rudna" a decrease in mean monthly air humidity is observed in comparison to the reference station in Polkowice throughout the year. The highest differences are noted from April to October (with a maximum difference of 10% at stations "Tarnówek" and "Kalinówka"). The performed tests show that mean hourly air humidity values undergo most significant changes influenced by the object on its surface ("Zapora" station). This is manifested in the flattening of the daily amplitude and in a noticeable shift in the time of occurrence of extreme daily values.

Tests conducted basing on the frequency of occurrence of air humidity in the predefined ranges: 0–20%, 20–40%, 40–60%, 60–80% and 80–100% throughout the day show that the TP has an influence on humidity conditions. This is proved by a significant drop in frequency of air humidity values from the range 80–100% at "Zapora" station in relation to the standard conditions represented by station "Polkowice". As far as frequency of occurrence of air humidity values from specific ranges is concerned, conditions most similar to those in Polkowice are recorded at station "Rudna", located the furthest from the object. The highest differences were observed between "Polkowice" and "Zapora".

Moreover, the conducted analysis shows that "Żelazny Most" influences a decrease in mean monthly temperature measured at 6 hours UTC. The largest changes are noted during the period lasting from April to September (the decrease in air temperature values ranges from 1.5 to 2°C). The said differences are slight in the winter period (December, January, and February). The courses of this value at stations located in the proximity of the object ("Tarnówek", "Kalinówka", and "Rudna") and on the object ("Zapora") are very similar. The analysis of measurements taken at midday shows that at this time of day the influence of "Żelazny Most" on mean monthly temperature is the lowest of all analysed measurement times. The course of mean monthly values throughout the year at measurement sites is the most similar to standard conditions. The tests confirm a noticeable increase in mean monthly air temperature at all measurement sites within the zone of influence of the TP measured at 18 hours UTC, in comparison to the measurements taken at the station of the Institute of Meteorology and Water Management in Polkowice. During the period from April to September most of the differences in mean monthly air temperature values at the station located on "Żelazny Most" and in its direct proximity exceed 2°C. A shift in the times of occurrence of daily minimum and maximum air temperatures is noted within the zone of influence of the object. In "Tarnówek" and in "Kalinówka" the daily maximum and minimum times are delayed in relation to those in "Polkowice" by an annual average of 2 hours, whereas at the "Zapora" the minimum is delayed by 3 hours and the maximum by 2 hours. A significant flattening of daily amplitude is observed at the measurement sites "Tarnówek", "Kalinówka" and "Zapora" (to the largest extent on the latter). As far as the daily course is concerned, "Rudna" is the most distinguished station along with "Zapora", due to the highest extreme values recorded there. The analysis of the daily course of frequency of occurrence of temperatures within predefined ranges is the tool that shows most clearly the influence of "Żelazny Most" on the temperature conditions on its surface. The most frequently observed air temperatures at the "Zapora" station fall within the range 10–20°C, and, at the same time, temperatures below 10°C are noted the least frequently. A correlation was found between the distance between the location of the measurement site and the pond and the frequency of recorded temperatures in the range 10–20°C. "Zapora" is characterized by the longest period of occurrence of such temperatures during the day, followed by "Kalinówka", while the lowest frequency is noted in "Rudna".

On the other hand, the test of significance of differences conducted for three variables: air humidity, temperature and wind speed on the basis of mean values at certain times (6, 12, 18 UTC), mean hourly and temporary values confirms the existence of differences in climate conditions between the area influenced by the object and the area representing standard conditions in this part of Lower Silesia, i.e. the station of the Institute of Meteorology and Water Management "Polkowice" in Polkowice. The test of significance of differences also confirms the hypothesis stating that the influence of the object on specific climate factors differs depending on the location and distance from "Żelazny Most".

The presented analysis leads to three main conclusions:

- Wind is the factor that undergoes the largest transformations under the influence of the tailing pond "Żelazny Most".
- The most significant modifications in wind speed are observed on the surface of "Żelazny Most". A significant increase in wind speed is noted here throughout the analysed period.
- The influence of "Żelazny Most" on the humidity and temperature conditions is manifested mainly through the flattening of daily amplitude and a shift in the times of occurrence of minimum and maximum recorded values.

This study presents some guidelines for the planning of a monitoring network, as the analysis proves that the influence of this type of objects differs depending on the location (on the surface of the object, in its direct or indirect proximity) and that the extent of changes is influenced by the location, topography and the dominant wind directions. The ability to evaluate the influence of such industrial object on local climate allows us to plan its adequate management and exploitation, taking into account the new processes that might occur under the influence of changing climate conditions and to organize various activities aimed at the prevention of disadvantageous changes to the environment.

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The Act on Mining Waste of the 10th of July, 2008 [Journal of Laws N°. 138/2008, item 865]

THE INFLUENCE OF THE TAILING POND "ŻELAZNY MOST" ON LOCAL CLIMATE

Summary

The present dissertation discusses the results of studies on the influence of the tailing pond "Żelazny Most" on local climate.

It analyses the measurements of air humidity, air temperature and wind speed recorded with use of automated meteorological stations Maws 101 manufactured by Vaisala, located in the proximity of the copper tailing pond "Żelazny Most" and at the station of the Institute of Meteorology and Water Management in Polkowice, in the years 2003–2009. Measurements were taken at four stations: "Tarnówek", "Zapora", "Kalinówka" and "Rudna", placed in different locations in relation to the deposit, and "Polkowice", representing the standard conditions, free from the influence of the object.

The influence of the tailing pond on local climate was evaluated with use of statistical methods, of which the most important are: the analysis of mean monthly and hourly values, daily course, frequency distribution, as well as the analysis of differences and testing statistical hypotheses (tests of significance of differences). Additionally, the study presents basic climate factors and the mechanisms of their operation.

The analysis of the measurement series obtained during the tests showed that the climate of the studied area is shaped under the influence of various physical properties of the soil, mainly the type of active surface and its properties, different surfaces: land, soil or water reservoir, the differences in plant cover or the absence thereof, which influences the changes in albedo and surface roughness. Another vital factor influencing the climate is the elevation above natural terrain surface.

The factor that undergoes the largest transformations influenced by the presence of the object is wind. The highest changes in wind speed are observed on the surface of "Żelazny Most". The differences between wind conditions at the measurement sites located at the foot of the tailing pond and the conditions at the station of the Institute of Meteorology and Water Management "Polkowice" are in most cases also statistically significant. In the daily course the highest increase in wind speed in comparison with the reference station "Polkowice" is noted at noon, whereas in the annual course – in spring and autumn. The increased wind speed on the surface of "Żelazny Most" leads to a reduction of temperature and humidity contrasts. The air humidity in the zone influenced by the pond is characterised by a visible daily and annual rhythm resulting from the influence of global (solar radiation) and local factors (proximity of the reservoir). It is manifested in form of a decrease in air humidity in the morning and an increase in the evening, and a decrease in spring and summer and an increase in autumn and winter. The highest differences in humidity conditions are observed between the reference station "Polkowice", and the surface of the tailing pond ("Zapora" station), where, additionally, a shift in the daily maximum and minimum times is observed. A clear correlation between air temperature and humidity is noticeable. The highest differences in air temperature between station "Polkowice" and measurement sites located within the zone influenced by the tailing pond are observed in the morning (the temperature in "Polkowice" is higher) and in the evening (the temperature in "Polkowice" is lower). This correlation is particularly visible in the period from April to September. On the surface of "Żelazny Most" a reduction of daily amplitudes is observed throughout the measurement period.

The obtained test results prove that the tailing pond has a significant influence on local climate. The strongest influence of the tailing pond is manifested in the increase of wind speed. The test results may serve as a basis for the creation of methodology for analysing the influence of industrial waste deposits on local climate. This study presents some guidelines for the planning of a monitoring network, as the analysis proves that the influence of this type of objects differs depending on the location (on the surface of the object, in direct or indirect proximity) and that the extent of changes is influenced by the location, topography and the dominant wind directions. The ability to evaluate the influence of such industrial object on local climate allows us to plan its adequate management and exploitation, taking into account the new processes that might occur under the influence of changing climate conditions and to organize various activities aimed at the prevention of disadvantageous changes to the environment.

Key words: Tailing pond, "Żelazny Most", local climate, air temperature, air humidity, wind speed

WPŁYW OBIEKTU UNIESZKODLIWIANIA ODPADÓW WYDOBYWCZYCH "ŻELAZNY MOST" NA KLIMAT LOKALNY

Streszczenie

Niniejsza monografia zawiera omówienie wyników badań oddziaływania obiektu unieszkodliwiania odpadów wydobywczych "Żelazny Most" na klimat lokalny.

Przeanalizowano pomiary wilgotności, temperatury powietrza oraz prędkości wiatru zanotowane za pomocą automatycznych stacji meteorologicznych Maws 101 firmy Vaisala, w rejonie składowiska odpadów flotacji miedzi "Żelazny Most" oraz na stacji Instytutu Meteorologii i Gospodarki Wodnej w Polkowicach, w latach 2003–2009. Pomiary wykonano na czterech stacjach obserwacyjnych "Tarnówek", "Zapora", "Kalinówka" i "Rudna", różnie zlokalizowanych względem składowiska oraz "Polkowice" przedstawiającej warunki standardowe, pobawione wpływu składowiska.

Do oceny oddziaływania składowiska na klimat lokalny zastosowano metody statystyczne, z których za najistotniejsze uznaje się analizę wartości średnich miesięcznych i godzinowych, przebiegu dobowego, rozkładu częstości, a także analizę różnic oraz testowanie hipotez statystycznych (testy istotności różnic). Ponadto w pracy przedstawiono podstawowe czynniki klimatyczne oraz mechanizmy ich działania.

Analiza serii pomiarowych uzyskanych w trakcie badań wykazała, że klimat obszaru badań kształtuje się pod wpływem różnych fizycznych właściwości podłoża, głównie rodzaju powierzchni czynnej i jej właściwości, różnych powierzchni: gruntu, gleby czy akwenu, zróżnicowania pokrywy roślinnej lub jej braku, co stanowi o zmienności albedo i szorstkości podłoża. Dodatkowym ważnym czynnikiem wpływającym na klimat lokalny jest wysokość położenia nad powierzchnią naturalnego terenu.

Wiatr jest czynnikiem podlegającym największym przekształceniom pod wpływem składowiska. Największe modyfikacje prędkości wiatru obserwowane są na powierzchni "Żelaznego Mostu". Różnice pomiędzy warunkami wietrznymi w punktach obserwacyjnych położonych u podnóża składowiska a warunkami na stacji IMGW "Polkowice" w większości przypadków są również istotne statystycznie. W przebiegu dobowym największy wzrost prędkości wiatru obserwuje się w godzinach południowych, natomiast w przebiegu rocznym wiosną i jesienią w stosunku do stacji bazowej ("Polkowice"). Wzrost prędkości wiatru na powierzchni "Żelaznego Mostu" powoduje wyrównanie kontrastów termicznych i wilgotnościowych. Wilgotność powietrza w rejonie oddziaływania składowiska charakteryzuje się wyraźnym rytmem dobowym i rocznym będącym efektem wpływu czynników globalnych (promieniowanie słoneczne) i lokalnych (bliskość akwenu). Przejawia się to poprzez spadek wilgotności powietrza w ciągu dnia i wzrost wieczorem oraz spadek wiosną i latem, a wzrost jesienią i zimą. Największa różnica w warunkach wilgotnościowych obserwowana jest pomiędzy stacją bazową "Polkowice" a powierzchnią składowiska (stacja

"Zapora"), na której dodatkowo stwierdza się przesunięcie dobowych minimów i maksimów. Pomiędzy temperaturą i wilgotnością powietrza widoczna jest wyraźna korelacja. Największe różnice temperatury powietrza pomiędzy stacją "Polkowice" a punktami obserwacyjnymi w strefie oddziaływania składowiska stwierdza się rano (w "Polkowicach" temperatura jest wyższa) oraz wieczorem (w "Polkowicach" temperatura jest niższa). Zależność ta jest szczególnie widoczna w okresie od kwietnia do września. Na powierzchni "Żelaznego Mostu" obserwuje się w całym okresie pomiarowym zmniejszenie amplitudy dobowej.

Uzyskane wyniki badań wskazują na istotny wpływ składowiska odpadów przemysłowych na klimat lokalny. Największe oddziaływanie składowiska przejawia się poprzez wzrost prędkości wiatru. Wyniki badań mogą posłużyć do stworzenia metodyki analiz oddziaływania składowisk odpadów przemysłowych na klimat lokalny. Niniejsze opracowanie daje również wskazówki do planowania sieci monitoringu badawczego. Wykazano, że oddziaływanie tego typu obiektów jest zmienne w różnych miejscach, na jego powierzchni i w dalszym lub bliższym sąsiedztwie. Na wielkość zmian wpływają położenie, topografia oraz przeważające kierunki wiatru. Możliwość oceny wpływu obiektu przemysłowego na klimat lokalny umożliwia zaplanowanie właściwej gospodarki i jego eksploatacji z uwzględnieniem nowych procesów, które mogą zaistnieć pod wpływem zmieniających się warunków klimatycznych oraz organizację różnych form przeciwdziałania niekorzystnym zmianom w środowisku.

Słowa kluczowe: obiekt unieszkodliwiania odpadów wydobywczych, "Żelazny Most", klimat lokalny, temperatura powietrza, wilgotność powietrza, prędkość wiatru