

A.V. Golushko

*Non-profit Joint Stock Company "Rudnensky Industrial Institute", Rudny, Kazakhstan
Corresponding author: achievement_7_11@mail.ru*

The study of the city of Rudny as a "heat island"

The annual increase in surface air temperatures contributes to climate change. This phenomenon is widespread over the entire surface of the Earth and is typical for any point of the planet. The purpose of this study was to identify patterns of changes in meteorological indicators in the city of Rudny, Kostanay region, Republic of Kazakhstan over the summer period 2018–2022. The scientific novelty of the work lies in the fact that for the first time the spatial distribution of the heat index in the territory of the city of Rudny was determined. To conduct the study, data from local automated weather stations were used, meteorological data was analyzed, compared for each year of the study, and the heat index was calculated. The reliability of the results is ensured by mathematical processing of daily empirical temperature and humidity data (calculation of the average for the day, the average for the month), coefficient of variation, coefficient of dispersion. The conducted research provides a clear description of climate changes in the city of Rudny, which can be used by municipal authorities to form measures to reduce the thermal impact on public health, heat loss in the housing and communal services system, and to improve air quality when planning urban infrastructure in the territory of the studied city.

Keywords: heat island, heat wave, heat index, coefficient of variation, coefficient of dispersion, meteorological indicator, trend line, atmospheric humidity, atmospheric temperature.

Introduction

According to Kazhydromet, over the past 100 years, the average annual temperature in Kazakhstan has increased by 1.5 degrees Celsius [1]. This situation indicates local climate change and implies an annual increase in surface air temperature indicators.

Therefore, the purpose of this study was to identify patterns of changes in meteorological indicators. The place of research is the city of Rudny. The summer period 2018–2022 was chosen for the study.

In accordance with the goal, the following tasks were set:

- study the factors influencing the formation and intensity of heat island propagation in the city of Rudny;
- analyze the temperature and humidity indicators for the summer period 2018–2022 for the city under study.
- calculate the heat index for the summer period 2018–2022 for the city under study.
- identify the relationship between changes in indicators in the city of Rudny over time (for the summer period 2018–2022).

The relevance of this work is determined by the intensive development of urbanization, which affects the local climate of the territory, characterized by the appearance of the so-called "heat island". The calculated data can be used by municipal authorities to formulate measures to reduce the heat impact on the health and life of the population, on heat losses in the housing and communal services system, and on improving air quality when planning urban infrastructure.

The scientific novelty of the work lies in the fact that for the first time the spatial distribution of the heat index over the territory of the city of Rudny was determined.

The object of research was the city of Rudny, Kostanay region, Republic of Kazakhstan.

The subject of the study was the indicators of temperature and humidity of atmospheric air, as well as the patterns of their interaction. These meteorological indicators for the summer period 2018–2022 were taken from the official website of Kazhydromet [1]. Data for the summer months of 2023 are not published on the site.

Materials and methods

Analyzing the urban “heat island” is one of the easiest ways to see how human impact can change our planet [2–4]. Urban “heat island” is a meteorological phenomenon that involves an increase in the temperature of urban space relative to the surrounding rural areas [5–8]. To identify the “heat island”, the difference between the values of the heat indices calculated from the temperature and humidity of atmospheric air is used [9–11].

The formation and intensity of the «heat island» spread is influenced by the following factors:

- geographical location;
- size of the city;
- specialization of the city;
- weather conditions;
- time;
- city type [12–15].

Each of these factors is considered in relation to the city of Rudny [16]:

1 Geographical location:

Rudny is a city located on the Tobol River in Kostanay region. The territory is characterized by a relatively flat terrain. Rudny is bordered by 2 cities (Kostanay, Lisakovsk) and 4 districts (Taranovsky, Auliekolsky, Fedorovsky, Altynsarinsky).

2 City size:

By the volume of the occupied territory, the city occupies the 2nd place in the region after Moscow, Kostanay and its area is 195.11 km².

3 Specialization of the city:

Rudny is a city of regional subordination. The city is rich in ore resources, including coal, iron ore and other metals. Its emergence is associated with the development of an iron ore deposit and the construction Sokolovsko-Sarbaysky Mining and Processing Plant (JSC SSGPO). This is a single-industry town.

4 Weather conditions:

The climate is sharply continental, with a pronounced alternation of four seasons. Winters are long and frosty, with strong winds and blizzards, and summers are hot and dry.

5 The time taken for the study is the summer season, with the vegetation available during this period and hot weather conditions.

6 City type:

city geometry: houses on the territory of the city are located in a block and parallel street system.

landscaping: there is a small amount of shrubby vegetation, trees, including those with pruned crowns — the vegetation is small.

materials: the asphalt surface strongly prevails, there is a mirror reflecting surface of buildings (windows, building cladding), metal and stone monuments on the territory of the city, metal lamp posts, a large flow of cars.

Having recognized the factors influencing the formation and intensity of the spread of the “heat island” in Rudny, then we consider the indicators of temperature and humidity of atmospheric air taken from the official website of Kazhydromet for the summer period 2018–2022 for 2 automated weather stations located in Rudny [1]:

Rudny PNZ No. 5 (S), Molodoy Gvardii str. / 4th pereulok.

Rudny PNZ No. 6 (S), Komsomolsky ave., mosque district.

Since data on meteorological indicators are available only for the PNZ No. 6 (S) weather station, then only these indicators will be used in the study.

After analyzing the temperature and humidity indicators of atmospheric air for the summer period 2018–2022, comparative graphs are constructed, presented in Figures 1 and 2.

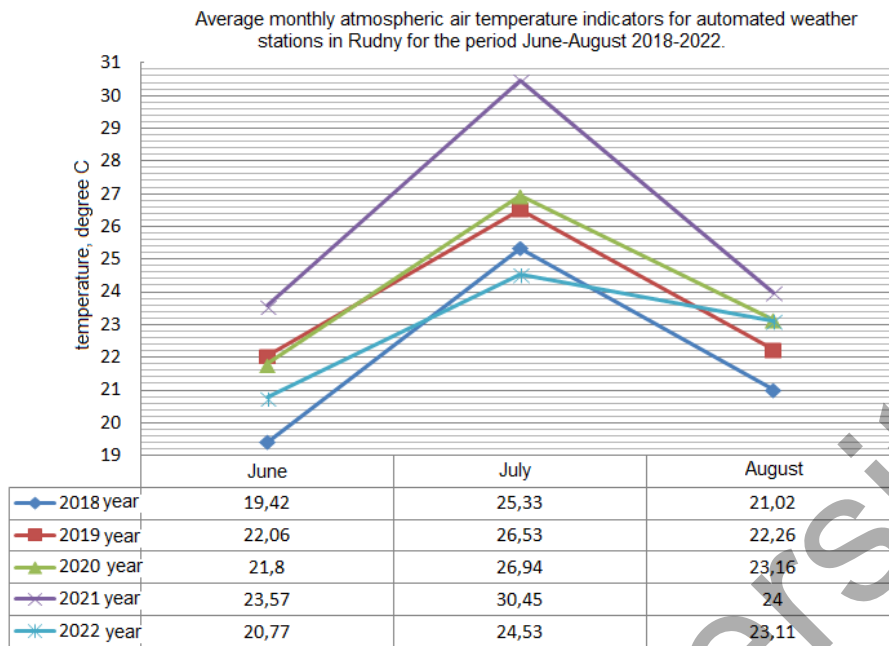


Figure 1. Monthly average air temperature indicators for the automated weather station PNZ No. 6 (S) in Rudny for the period June-August 2018–2022

According to the graph, the following conclusions were drawn on the monthly average atmospheric temperature indicators for the automated weather station PNZ No. 6 (S) in Rudny for the period June-August 2018–2022:

1. The highest annual figures for atmospheric air temperature, among those presented, were revealed in 2021, and the lowest — in 2018.
2. High temperature indicators are more pronounced in July and less pronounced in June.
3. Every year there is an increase in the average value of atmospheric air temperature by about 0.5–1.5°C.

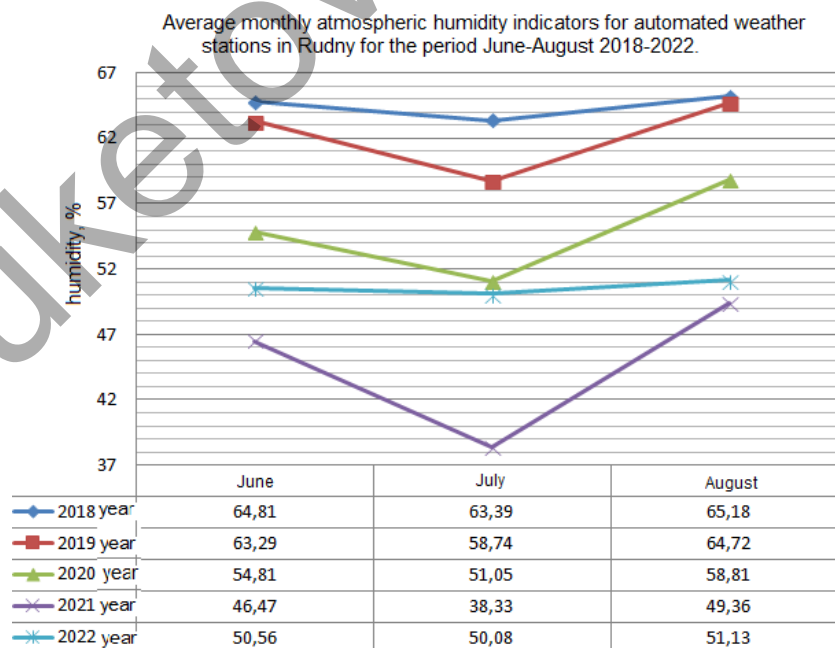


Figure 2. Monthly average atmospheric humidity indicators for the automated weather station PNZ No. 6 (S) in Rudny for the period June-August 2018–2022

According to the constructed schedule, the following conclusions were drawn on the average monthly atmospheric humidity indicators for the automated weather station PNZ No. 6 (S) in Rudny for the period June–August 2018–2022:

1. The highest annual humidity indicators were revealed in 2018, and the lowest — in 2021.
2. Indicators of high humidity are more pronounced in August, less so in June.
3. Every year there is a decrease in the average value of atmospheric humidity by about 7–15 %.

The calculated coefficients of variation and variance presented in Table 1 are used to confirm changes in meteorological indicators for the summer period 2018–2022.

According to the calculated values, a conclusion is made on the coefficients of variation and variance based on the data of atmospheric temperature and humidity for the period June–August 2018–2022. The greater the difference between the resulting coefficients, the more the initial data differ from the average (normal for the region and season) indicators, i.e. there are abrupt changes in the indicators.

The study uses the following methods:

- to obtain data on the regularities of the formation of “heat island”: study and determine the factors of formation and intensity of the spread of “heat island” in the city under study;
- to collect initial weather data in the object under study: method for analyzing weather station data, HORIBA software package, Kazhydromet official website <https://www.kazhydromet.kz>;
- for mathematical data processing, identifying trends in their changes, and visualizing results: the capabilities of the Excel, Google Earth, and Humindex computer programs.

Table 1

Coefficients of variation and variance based on atmospheric temperature and humidity data for the period June–August 2018–2022

Year	Coefficient of variation, %		Coefficient of variance	
	According to temperature data	According to humidity	According to temperature	According to humidity
2018	15,33	10,23	0,46	0,56
2019	11,82	10,89	0,27	0,64
2020	13,76	14,37	0,37	1,10
2021	3,61	6,91	0,02	0,25
2022	9,17	2,42	0,16	0,03

Results and Discussion

Having the values of temperature and humidity of atmospheric air, it is possible to calculate the heat index using the online calculator Humindex. This indicator is necessary to determine the equivalent temperature perceived by a person [17].

Based on the calculated heat index data for the period June–August 2018–2022 for the automated weather station PNZ No. 6 (S) in Rudny, presented in Table 1 of Appendix A, the following conclusions are drawn:

This indicator has low values in the morning, compared to the rest, and high values are seen in the daytime.

The lowest indicator in the summer season (5.8-morning) was revealed in 2018, the highest (37.9-day) — in 2019.

After analyzing the heat index indicators for the summer period 2018–2022, comparative graphs are constructed, shown in Figure 3.

According to the World Meteorological Organization, heat waves are considered to be a period with a maximum daily air temperature exceeding the average maximum temperature by 5⁰C or more, lasting continuously for 5 days or more [18]. In the branch of RSE “Kazhydromet” in Kostanay region, there are data on the average maximum air temperature in the summer season for the city of Rudny and are equal to: in June +19.9⁰C, in July +21.1⁰C, in August +18.9⁰C [19]. These values are determined based on already available data for the last 50 years for the city under study. The impact of heat waves on climate change is significant [20]. This is also typical for the Republic of Kazakhstan. The phenomenon affects every city in the country, including the city of Rudny (the object of research).

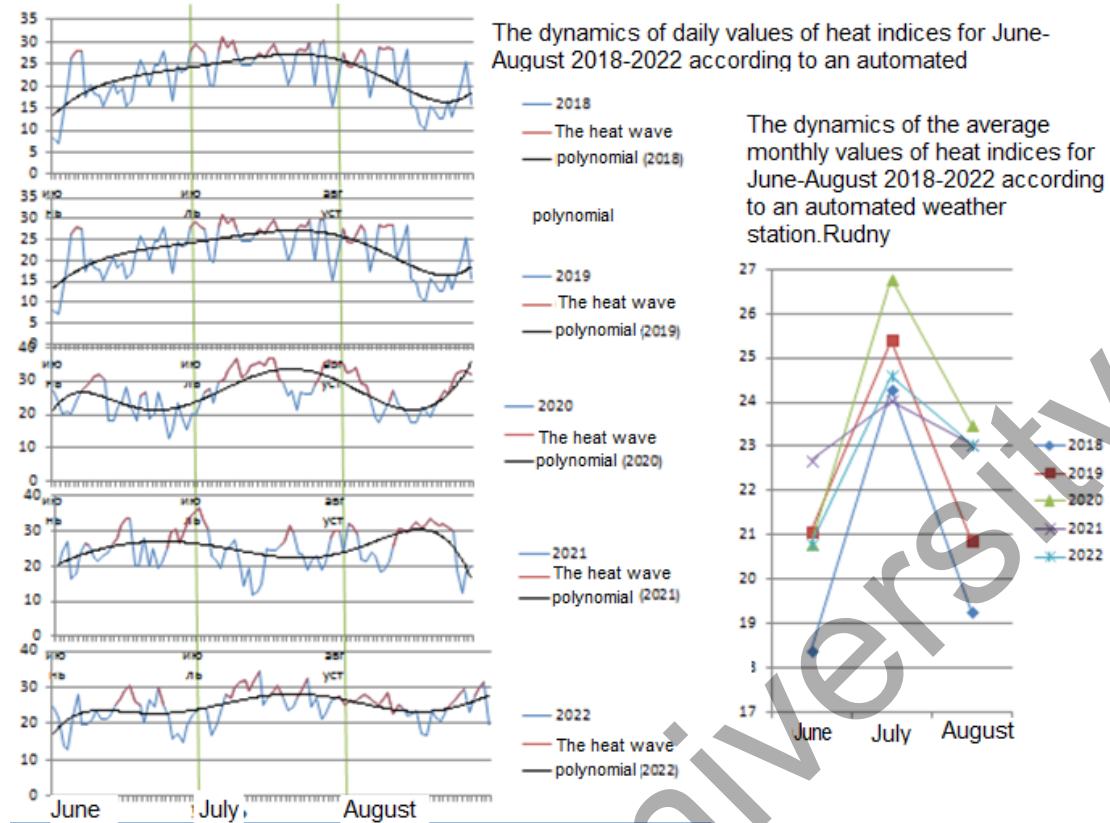


Figure 3. Heat index indicators for the summer period 2018–2022

According to the constructed graphs, the following conclusions were drawn on the heat index indicators for the summer period 2018–2022:

1. Thanks to the built-up trend lines, the variability of the heat index indicators by month can be clearly traced. Since mid-June, the index has been growing, and by mid-August it is declining.
2. Over the years, the dynamics of increasing the values of the thermal index is noticeable.
3. The lowest overall figures were found in 2018, and the highest overall figures were found in 2020.

The increased risk of heat waves affecting human health can be traced in the daytime during the entire summer season. The average duration of heat waves is 7–16 days. The intervals between them are 5–10 days. At least 1 heat wave is recorded every month, and most of them are traced in July and August.

Table 2 shows the number of days with increased heat index values and the number of heat waves during the study period.

According to the calculated values, conclusions are drawn on the number of days with increased heat index values and the number of heat waves for the period June-August 2018–2022.:

1. The month of June is least affected by heat waves and increased heat index values.
2. The months of July and August are comparatively similar.
3. Data for 2020 are presented as anomalous.

Table 2

The number of days with increased heat index values and the number of heat waves for the period June-August 2018–2022

Month	Total number of days with increased heat index values / number of heat waves				
	2018		2018		2018
June	5/-6	June	5/-6	June	5/-6
July	21/2	July	21/2	July	21/2
August	12/1	August	12/1	August	12/1
TOTAL:	38 days / 3 heat waves	TOTAL:	38 days / 3 heat waves	TOTAL:	38 days / 3 heat waves

Conclusions

As a result of the research work, the goals and objectives set earlier were fulfilled and the following conclusions were obtained:

1. The following regularities of changes in the temperature and humidity of atmospheric air in the city of Rudny during the studied period were revealed:

– During the summer period 2018–2022, there is an annual increase in the average value of atmospheric air temperature by about 0.5–1.5 °C and a decrease in the average value of atmospheric air humidity by about 7–15 % during the summer months;

– Among the summer months, the month of June is distinguished by low temperature and humidity indicators for the entire study period, the month of July is distinguished by high temperature values, and the month of August is characterized by high data on atmospheric humidity in the city of Rudny.

2. The regularity of the peak temperature and the values of the heat index in the daytime, respectively, and the greatest danger of finding a person in the open air is confirmed. The safest time for a person is in the morning.

3. During the period June–August 2018–2022, an increase in the number of days with a high heat index is observed. Heat waves can be traced in the summer period 2018–2022.

4. Since 2020, there has been a jump in the increase in meteorological indicators, and this trend continues.

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А.В. Голушко

Рудный қаласын «жылу аралы» ретінде зерттеу

Жер бетіндегі ауа температурасының жыл сайынғы жоғарылауы климаттың өзгеруіне ықпал етеді. Бұл құбылыс Жердің бүкіл бетіне кең таралған және планетаның кез келген нүктесіне тән. Зерттеудің мақсаты 2018–2022 жылдардағы жазғы кезеңде Қостанай облысы Рудный қаласындағы (Қазақстан) метеорологиялық көрсеткіштердің өзгеру заңдылығын анықтау. Жұмыстың ғылыми жаңалығы мынада: алғаш рет Рудный қаласының аумағында жылу көрсеткішінің кеңістікте таралуы анықталғанында. Зерттеуді жүргізу үшін жергілікті автоматтандырылған метеостанциялардың мәліметтері пайдаланылды, метеорологиялық деректерге талдау жасалды, зерттеудің әрбір жылына салыстыру жүргізілді және жылу индексі есептелді. Нәтижелердің сенімділігі температура мен ылғалдылықтың тәуліктік эмпирикалық деректерін математикалық өңдеу арқылы қамтамасыз етілді (орташа тәуліктік, орташа айлық есептеу), яғни вариация коэффициенті және дисперсия коэффициенті. Зерттеу Рудный қаласы бойынша климаттың өзгеруіне нақты сипаттама береді, оны муниципалды органдар тұрғындардың денсаулығына жылу әсерін, тұрғын үй-коммуналдық шаруашылық жүйесіндегі жылуды жоғалтуды азайту және зерттелетін қаланың аумағында қалалық инфрақұрылымды жоспарлау кезінде ауа сапасын жақсарту шараларын қалыптастыру үшін қолдана алады.

Кілт сөздер: жылу аралы, жылу толқыны, жылу индексі, вариация коэффициенті, дисперсия коэффициенті, метеорологиялық көрсеткіш, тренд сызығы, атмосфералық ауаның ылғалдылығы, атмосфералық ауа температурасы.

А.В. Голушко

Исследование города Рудный как «острова тепла»

Ежегодное повышение температурных показателей приземного воздуха способствует изменению климата. Данное явление распространено по всей поверхности Земли и характерно для любой точки планеты. Целью данного исследования являлось выявление закономерности изменения метеорологических показателей в городе Рудном Костанайской области (Казахстан) за летний период 2018–2022 годов. Научная новизна работы заключается в том, что впервые было определено пространственное распределение индекса тепла на территории города Рудного. Для проведения исследования использовались данные местных автоматизированных метеостанций, проводился анализ метеорологических данных, их сравнение за каждый год исследования, а также вычислялся индекс тепла. Достоверность результатов обеспечивалась математической обработкой ежедневных эмпирических данных температуры и влажности (подсчет среднего за день, среднего за месяц), коэффициента вариации, коэффициента дисперсии. Проведенное исследование дало четкую характеристику изменениям в климате по городу Рудному, которая может использоваться муниципальными органами для формирования мер по уменьшению теплового воздействия на здоровье населения, на потери тепла в системе жилищно-

коммунального хозяйства, на улучшение качества воздуха при планировании городской инфраструктуры на территории исследуемого города.

Ключевые слова: остров тепла, волна жары, индекс тепла, коэффициент вариации, коэффициент дисперсии, метеорологический показатель, линия тренда, влажность атмосферного воздуха, температура атмосферного воздуха.

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Information about the author

Golushko Anastasiya Vladimirovna — Master of natural sciences, Lecturer at the Higher school of Energy and information systems of the Non-profit Joint Stock Company “Rudnensky Industrial Institute”, Rudny, Kazakhstan, e-mail: achievement_7_11@mail.ru.

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