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« \_\_\_\_\_ » \_\_\_\_\_ 2022

## BACHELOR THESIS

(EXPLANATORY NOTE)

SPECIALTY 101 “ECOLOGY”,  
EDUCATIONAL AND PROFESSIONAL PROGRAM:  
“ECOLOGY AND ENVIRONMENT PROTECTION”

**Theme:** «Defining and mapping of pollution from thermal power plants under the martial law condition»

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(student, group, surname, name, patronymic)

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KYIV 2022

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ  
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ  
ФАКУЛЬТЕТ ЕКОЛОГІЧНОЇ БЕЗПЕКИ,  
ІНЖЕНЕРІЇ ТА ТЕХНОЛОГІЙ  
КАФЕДРА ЕКОЛОГІЇ

ДОПУСТИТИ ДО ЗАХИСТУ  
Завідувач випускової кафедри  
\_\_\_\_\_ Т. В. Дудар  
« \_\_\_\_\_ » \_\_\_\_\_ 2022 р.

**ДИПЛОМНА РОБОТА**  
**(ПОЯСНЮВАЛЬНА ЗАПИСКА)**

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ БАКАЛАВРА

ЗА СПЕЦІАЛЬНІСТЮ 101 «ЕКОЛОГІЯ»  
ОПП «ЕКОЛОГІЯ ТА ОХОРОНА НАВКОЛИШНЬОГО СЕРЕДОВИЩА»

**Тема: «Визначення та картування  
забруднень від теплових  
електростанцій в умовах воєнного  
стану»»**

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КИЇВ 2022

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Head of the Department

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« \_\_\_\_\_ » \_\_\_\_\_ 2022

**BACHELOR THESIS ASSIGNMENT**

Vitalii V. Rozhko

1. Theme: «Defining and mapping of pollution from thermal power plants under the martial law condition» approved by the Rector on September 18.04.2022 № 388/CT.
2. Duration of work: from 23.05.2022 to 19.06.2022.
3. Output work (project): published data on the Trypillya thermal power plant functioning and environmental conditions; space images of the Landsat 8 satellite; Google Earth Engine.
4. Content of explanatory note: (list of issues): Analytical review of the literature on the topic of the diploma. Determination and mapping of pollution of the territory of the thermal power plant using diverse data of satellite survey.
5. The list of mandatory graphics (illustrated materials): tables, figures, charts, graphs, space images.

## 6. Schedule of thesis fulfillment

№ з/П	Task	Term	Advisor's signature
1	Receive themes task, search the literature and legislation	08.04.2022	
2	Preparing the main part (Chapter I)	23.05- 29.05.2022	
3	Preparing the main part (Chapter II)	30.06- 01.06.2022	
4	Correcting and rereading of the main parts	02.06- 04.06.2022	
5	Formulating conclusions and recommendations of the thesis	05.06.2022	
6	Making an explanatory note to the previous presentation of the department, consultation with the norms controller	05.06 - 07.06.2022	
7	Presentation of the work at the department	08.06.2022	
8	Taking into account the comments and recommendations and training to protect	09.06 - 13.06.2022	
9	Thesis defense at the department	14.06.2022	

7. Date of task issue: «23» 05 2022

Diploma (project) advisor: \_\_\_\_\_ Dudar T.V.  
(advisor's signature) (S.N.P.)

Task is taken to perform: \_\_\_\_\_ Rozhko V.V.  
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# НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Факультет екологічної безпеки, інженерії та технологій

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ОПП «Екологія та охорона навколишнього середовища»

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ЗАТВЕРДЖУЮ

Завідувач кафедри

\_\_\_\_\_ Дудар Т. В.

«\_\_\_\_\_» \_\_\_\_\_ 2022 р.

## ЗАВДАННЯ

на виконання дипломної роботи

Рожка Віталія Валеріановича

1. Тема: «Визначення та картування забруднення від ТЕС в умовах воєнного стану» затверджена постановою ректора від 18.04.2022 р. № 388/ст.
2. Тривалість роботи: з 23.05.2022 по 19.06.2022.
3. Вихідна робота (проект): опубліковані дані щодо функціонування Трипільської ТЕС та умов навколишнього середовища; космічні знімки супутника Landsat 8; Google Earth Engine.
4. Зміст пояснювальної записки: (перелік питань): Аналітичний огляд літератури за темою диплома. Визначення та картування забруднення території ТЕС з використанням різноманітних даних супутникової зйомки.
5. Перелік обов'язкових графічних (ілюстрованих матеріалів): таблиці, рисунки, діаграми, графіки, космічні зображення.

## 6. Календарний план-графік

№ з/п	Завдання	Термін виконання	Підпис керівника
1	Отримання теми завдання, пошук літературних джерел та законодавчої бази	08.04.2022	
2	Підготовка основної частини (Розділ I)	23.05-29.05.2022	
3	Підготовка основної частини (Розділ II)	30.06-01.06.2022	
4	Формулювання висновків та рекомендацій дипломної роботи	05.06.2022	
5	Оформлення пояснювальної записки до попереднього представлення на кафедрі, консультація з нормоконтролером	05.06 -07.06.2022	
6	Представлення роботи на кафедрі	08.06.2022	
7	Урахування зауважень, рекомендацій та підготовка до захисту	09.06 -13.06.2022	
8	Захист дипломної роботи на кафедрі	14.06.2022	

7. Дата видачі завдання: « 23 » 05 2022 р.

Керівник дипломної роботи (проекту): \_\_\_\_\_ Дудар Т. В.  
(підпис керівника) (П.І.Б.)

Завдання прийняв до виконання: \_\_\_\_\_ Рожко В.В.  
(підпис випускника) (П.І.Б.)

## **ABSTRACT**

The object of research is air pollution of the territories around thermal power plants.

The subject of research is remote methods of determination and mapping of air pollution by thermal power plants.

The aim of the work was to determine and map the air pollution of the areas around thermal power plants based on heterogeneous data from satellite imagery and the web platform for cloud geospatial calculations Google Earth Engine.

Research methods: analytical, remote, geoinformation, statistical methods of information processing.

Diploma thesis is devoted to the topic of thermal and chemical contamination of the environment from the thermal power plants functioning on the example of the Trypillya TPP.

ATMOSPHERIC POLLUTION, THERMAL POWER PLANTS, REMOTE METHODS, SATELLITE DATA, GOOGLE EARTH ENGINE

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## **LIST OF SYMBOLIC NOTATIONS, ABBREVIATIONS AND NOTIONS**

GDP – Gross domestic product;

TPP – Thermal Power Plant;

MV – MegaWatt;

AI – Air Quality Index;

## INTRODUCTION

***Relevance of the work.*** The use of fossil fuels for energy production, space heating is common. However, excessive and irrational use of such fuels leads to serious consequences, the main of which is the negative impact on public health and climate change. Therefore, prompt and regular detection of air pollutants, together with environmental monitoring is a key area for sustainable development. territories and, as a consequence, improving air quality. In the modern era of digital technologies, satellite imagery has become a reliable source of data for environmental monitoring. Satellite monitoring of air quality and geospatial analysis of the obtained data is a powerful information tool in making management decisions to achieve sustainable development goals, as well as to increase the level of ecologization in the country.

National vision for separating further economic growth and social development from increasing greenhouse gas emissions, especially due to thermal power plants, set out in low-carbon development strategy by stakeholders for Ukraine, developing such a strategy is the first experience of a synergistic approach in key sectors of the economy and the main components of human life. At the national level, it is a tool for public administration and the formation of climate-responsible behavior of businesses and citizens and supports the global goal of stabilizing GHG concentrations in accordance with the scenario of keeping global average temperatures below 2 ° C from pre-industrial levels.

At the same time, the national report "Sustainable Development Goals: Ukraine" one of the tasks of sustainable development of cities and communities (goal 11) noted the reduction of negative impacts of pollutants, including on the urban environment, in particular through the use of innovative technologies. Among the indicators of achieving the goal are: the volume of air pollutants,% to the level of 2015 (11.5.1), the total volume of air pollutants from stationary and mobile sources, conditionally reduced to carbon monoxide, taking into account the relative aggressiveness of major pollutants ,% to the level of 2015 (11.5.2 and 11.5.3) and the number of cities in which the average daily concentrations of major pollutants in the air exceed the average daily maximum allowable

concentrations (11.5.4).

Given the current challenges facing the country, the identification and mapping of pollution from thermal power plants by remote sensing is particularly relevant.

***Aim of the work*** – air pollution of the territories around thermal power plants.

The subject of research is remote methods of determination and mapping of air pollution by thermal power plants.

The aim of the work was to determine and map the air pollution of the areas around thermal power plants based on heterogeneous data from satellite imagery and the web platform for cloud geospatial calculations Google Earth Engine.

***Tasks of the work:***

1. Analyze the impact of heat energy facilities on the environment
2. Describe and determine the features of the impact of Trypillya TPP
3. Identify and map thermal pollution of the area of Trypillya TPP according to Landsat satellites
4. Identify and map air pollution according to the TROPOMI sensor of the Sentinel-5P satellite

***Object of research*** - was the identification and mapping of air pollution around thermal power plants based on diverse satellite imagery data and the Google Earth Engine web geospatial computing web platform.

***Subject of research*** – is an observation of air pollution of the territories around thermal power plants.

***Methods of research*** – analytical, remote, geoinformation, statistical methods of information processing.

***Scientific novelty:*** an approach to the definition and mapping of air pollution around thermal power plants is proposed based on heterogeneous satellite imagery data and the web platform for cloud geospatial calculations Google Earth Engine. A comprehensive analysis of thermal pollution of Trypillya TPP, as well as the annual dynamics of concentrations of carbon monoxide, sulfur dioxide, nitrogen dioxide to study air quality in Obukhiv district of Kyiv region and inform interested urban communities about the environmental situation in the surrounding areas of Trypillya.

**Practical significance:** the results of the research were used for teaching the disciplines of the educational-scientific program "Remote Aerospace Research of the Environment" in the specialty 103 - Earth Sciences and conducting practical classes with students of the Department of Ecology, Faculty of Environmental Safety, Engineering and Technology NAU. -technical cooperation between NAU and TsAKDZ № 30-nt-18 dated 04.12.2018

**Personal contribution of the graduate:** analysis of scientific literature on the topic, remote sensing of air pollution based on heterogeneous data from satellite imagery and web platform for cloud geospatial calculations Google Earth Engine, processing and analysis of results, preparation for the implementation of research results.

**Approbation of results.**

1. XVI Всеукраїнської науково-практичної конференції молодих учених і студентів
2. *Екологічна безпека держави 2020, 2021, 2022*
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4. *Міжнародний науковий симпозиум «Тиждень еколога – 2021»*

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Рожко В.В. Екологічні проблеми ТЕС під час військових дій. *Екологічна безпека держави 2022*: тези доповідей XVI Всеукраїнської науково-практичної конференції молодих учених і студентів (м. Київ, 21 квітня 2022 р.). Київ. 2022. С. 31

Рожко В.В. Outdoor air cleaning technologies. *Екологічна безпека держави 2020*: тези доповідей XIV Всеукраїнської науково-практичної конференції молодих учених і студентів (м. Київ, 23 квітня 2020 р.). Київ. 2020. С. 53

Рожко В.В. Моніторинг якості повітря міста Києва. *Екологічна безпека держави 2021*: тези доповідей XV Всеукраїнської науково-практичної конференції молодих учених і студентів (м. Київ, 22 квітня 2021 р.). Київ. 2021. С. 90

Rozhko V.V. Air quality and monitoring in the city of Kyiv. *Impact of modernity on science and practice*: Abstracts of VIII International Scientific and Practical Conference. (Madrid, 6-7 April 2021). Madrid, 2021. P. 158-160.

Лубський М.С. Рожко В.В. Картування джерел теплового забруднення антропогенного походження на прикладі міста Києва. *Міжнародний науковий симпозіум «Тиждень еколога – 2021»*: (м. Київ, 18-20 жовтня 2021 р.). Київ. 2021. С. 138-139

# CHAPTER 1

## SATELLITE MONITORING AS A POWERFUL TOOL FOR DETECTING THE IMPACT OF HEAT ENERGY ON THE ENVIRONMENT

### **1.1 Impact of heat energy on the environment. The main air pollutants.**

Atmospheric air is the main habitat of the biosphere, in particular man. The main gases of the atmosphere (nitrogen, oxygen, argon) are essentially transparent to long-wave and short-wave radiation and scatter it. The environment is significantly affected by gaseous impurities, which can be of natural and anthropogenic origin. Their natural sources include wind erosion, removal of salts from the surface of the seas and oceans, volcanic and biological processes, and space travel. One of the main sources of environmental pollution is thermal power plants.

Gaseous and aerosol pollutant emissions and their harmful effects. Combustion of liquid and solid fuels releases emissions in the form of solid particles that form so-called aerosols when released into the atmosphere. Aerosols can be non-toxic, low-toxic and toxic. Aerosols and solid particles can enter the atmosphere already formed (dust, ash, soot). A significant part of them is formed directly in the atmosphere as a result of chemical reactions between gaseous, liquid and solid substances, including water vapor. They are formed as a result of natural processes, although many of them are of anthropogenic origin. From 1-3 billion tons/year of particles of different chemical composition less than 1  $\mu\text{m}$  in size, formed above the Earth's surface, about 20% - the result of human activities (dust, saturated substances, toxic metals: lead, mercury, cadmium, etc.; pesticides).



Fig. 1.1. View on the main hull of the Trypillya TPP

In the material balances of combustion of solid and liquid fuels, solid combustion products - ash - play a certain role. The ash content of fuel is called ballast in the calculation of dry mass of fuel. It depends on the nature of the fuel and the quality of its production. There is primary ash - residues of mineral impurities that were part of the fuel during its processing, secondary ash - foreign minerals, evenly distributed in the fuel, and the rock - minerals that got into the fuel during its extraction.



Fig 1.2 The sludges across the road near the Trypillya TPP

## **1.2 Current tasks of pollution detection of thermal power plants to prevent climate change and ensure sustainable development of territories**

Ukraine has committed itself to reducing greenhouse gas emissions by 40% by 2030 compared to 1990. However, the great path of decarbonization of the country is just beginning, in particular, in the framework of the "Paris Agreement" - "National Defined Contribution-2".

Ukraine has close economic cooperation with the countries of the European Union in many areas, so it actively supports all environmental initiatives, including the European Green Deal. Moreover, the EU sees Ukraine as one of its strategic partners in hydrogen production, an environmentally friendly energy source that can be a full-fledged replacement for natural gas.

At the same time, Ukrainian industry spends much more energy to create a unit of goods, and therefore creates more emissions of carbon and harmful substances and is less competitive in foreign markets.

There is a direct relationship between the level of energy consumption and the amount of harmful emissions: the more energy consumed; the more harmful substances are released into the environment.

Especially - given the significant share of coal generation in the energy balance of Ukraine (almost 40%). The introduction of energy efficiency measures is one of the steps that will make Ukrainians not only richer but also healthier.

According to the annual global survey Energodata, the level of energy intensity of Ukraine's gross domestic product (GDP) is twice the world average. For example, the level of energy intensity of Poland's GDP is 2.5 times lower than in Ukraine, Germany - 3.3 times.

In other words, the production of a unit of goods at a Ukrainian enterprise requires 2.5 times more energy than in Poland.

Ukraine, like other UN member states, has joined the global process of sustainable development. In order to establish the strategic framework of Ukraine's national development for the period up to 2030, an inclusive process of adaptation of



the CSW was launched on the basis of the principle "Nobody should be left out". Each global goal was considered taking into account the specifics of national development. During 2016, a number of national (4) and regional (10) consultations were held in Ukraine. The consultations suggest that national CSBs will serve as a basis for integrating efforts to ensure economic growth, social justice and environmental management.

Methods of remote monitoring of air quality will help to identify the main sources of pollution, and will ensure the implementation of task 11.5 of the CSB. Identifying these foci will help reduce emissions and improve the environmental situation in a given area. As we can see in our times the problem of territory pollution by Thermal Power Plants is sharp and needed to be reduced or even fully stop their operations. Gladly the humanity already creates more ecological and even more efficient way of production energy and heat.

### **1.3 Environmental problems of thermal power plants during hostilities**

The conflict on the territory of Ukraine takes part on one of the most heavily industrialized and polluted territories. The inheritance of Soviet heavy industry was already a public health problem but the Russian aggression risks further damage to the ecosystems on which people live. The ecological impacts of the armed conflict are a reminder that even when the war reaches its end, the damage will be felt for generations to come.

The armed conflict on the territory of Ukraine leads to a significant increase in the interconnected man-made and environmental threats to the population, in particular due to violations of the technological regime of numerous dangerous objects.

The concentration of a large number of dangerous objects and the high population density on the territory of Ukraine have contributed to the formation of significant threats to the death of the population from emergencies, even in peacetime. In the context of armed conflict, these threats have intensified significantly. This is not only due to the destruction and damage of enterprises due to the impact of shells of various calibers during hostilities. Violations of the regime of proper operation of hazardous facilities and the lack of replacement or renewal of their main production facilities play a significant negative role in the state of technogenic and environmental safety.

One of the options for ensuring an acceptable level of technogenic and environmental safety of the region is proper control, assessment and forecasting of the parameters of the state of dangerous objects to prevent and reduce the risk of emergencies and minimize their consequences.

As a result of enemy shelling, the facts of explosions at thermal power plants, destruction of gas pipelines and gas distribution stations were recorded. The fighting itself poses no less dangers: spilled fuel, destroyed equipment and spent weapons, exploded missiles - all of which contaminate the soil and groundwater with chemicals and heavy metals.

Thus, on February 24, an enemy bomb exploded on the territory of Trypillya TPP, which is located on the Dnieper coast 45 km south of Kyiv and is the largest supplier of

electricity in Kyiv, Cherkasy and Zhytomyr regions.



Fig. 1.3 As of 5 p.m., the occupiers fired a projectile into the coal depot of Trypillya TPP

The armed conflict on the Ukraine territory is taking place among a cautiously growing optimism about our opportunity to protect the environment during war as well as hold states and individuals responsible for wartime ecological harm. Until recently, the environmental consequences of war and war conflicts have been ignored in transborder politics. The latest innovations such as the codification of the principles for the ecological protection in relation to wars by the UN International Law Commission, expected to be implied in 2022, and propose the new legal determination of ecocide have given the optimism for legal accountability and remedy for environmental harm during war conflicts. Expansion of the mandate of the International Criminal Court to add crimes against the nature further strengthens the cause, even if the threshold for decisive evidence may be unusually challenging during an active conflict. Disruptions in to the regular monitoring, lack of access to sites where the war happens, unreliable data in social media as well as direct disinformation all contribute to this hardening. The latter but not least

indicates possibly planned “false flag” operations, such as Russians often use with biological, chemical and even radioactive substances, as environmental information can be used as high caliber weapon in media sources.

Besides supporting and assessment of the main data and lending a helping hand to weakened one’s environmental authorities at all main levels, the European and international community should also get prepared to make large efforts to support the post-war recovery of the Ukraine, including restoration of the environment, biota and nature at all.

#### **1.4. Conclusions to chapter 1**

As a result of overview and data analyses concerning to the TPP impact on the environment one can say the following:

1. Thermal energetics in case of fossil fuel combustion generate a large amount gaseous pollutant that have a large impact on the environment and the trend on the climate change.
2. Cooperation with other countries, especially EU countries, can dramatically increase the level of ecological understanding in term of environmental protection and take under control the emissions from TPP in Ukraine.
3. The war on the territory of Ukraine have nearly unrecoverable impact on the nature and on humans itself. The great part of Ukrainian hazardous facilities was intentionally damaged or destroyed by occupation forces.

## **CHAPTER 2**

# **DETERMINATION AND MAPPING OF POLLUTION OF THE TERRITORY OF THE THERMAL POWER PLANT USING DIVERSE DATA OF SATELLITE SURVEY**

### **2.1. Remote sensing methods in the detection of gas and thermal pollution of thermal power plants**

In recent years, satellite remote sensing has become an important method of monitoring air pollutants such as CO and CO<sub>2</sub>, NO<sub>x</sub>, SO<sub>2</sub>, including monitoring changes in these pollutants globally and regionally, their movements, estimating their emissions and determining concentrations in the near-surface atmosphere. Compared to ground-based observations, satellite measurements can provide data with higher spatiotemporal resolution and global coverage. Products on the concentrations of these pollutants are now available from satellite instruments such as Global Ozone Monitoring.

Experiment (GOME, 1995–2011), scanning image absorption spectrometer for atmospheric cartography (SCIAMACHY, 2002–2012), ozone monitoring instrument (OMI, since 2004) and TROPOspheric Monitoring Instrument (TROPOMI, since 2012).

Google Earth Engine (GEE) is a fast-growing geospatial processing service that offers a platform for the scientific analysis and visualization of geospatial datasets for users from academia, nonprofits, business and government. Earth Engine contains a huge number of satellite images and stores them in a public data archive that contains historical images of the Earth that are over forty years old. Images that arrive daily are then made available for global data analysis. Earth Engine also provides APIs and other tools for analyzing large data sets.

## 2.2 Characteristics of the research area and its environmental problems

Determination and mapping of air pollution in the area of the thermal power plant by remote methods was carried out on the example of Trypillya TPP, which is located near Ukrainka, Obukhiv district, Kyiv region. The territory of Obukhiv district was chosen for research (Fig. 2.1).

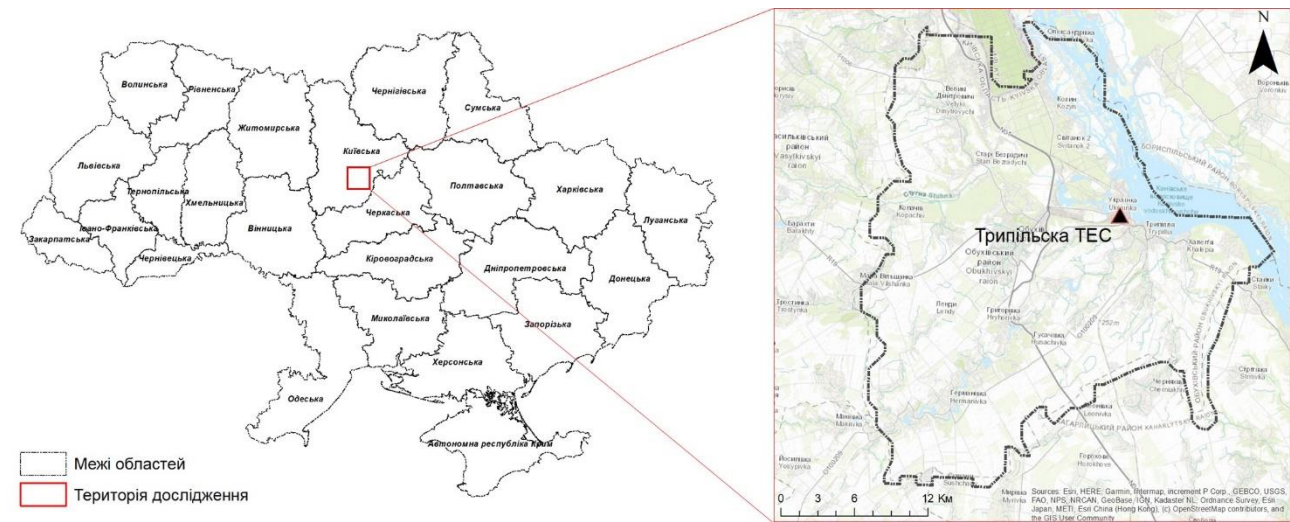


Fig. 2.1. Location of Trypillya TPP within the study area

Obukhiv district of Kyiv region (with the administrative center in the city of Obukhiv) was formed as part of Boguslav city, Vasytkiv city, Kagarlyk city, Kozyn village, Myroniv city, Obukhiv city, Rzhyschiv city, Ukrainian city, Feodosiiv and rural districts of Ukraine.

Population of the district: 229518.

Area of the district: 3639 km<sup>2</sup>

Located in the north of Ukraine, in the Polissya zone (temperate-continental climate). It is located 45 km south of Kyiv. Obukhiv's climate is a bit hotter than Kyiv. The tributary of the Dnieper, the Kobrynka River, flows through the city.

The average annual temperature is +8.6 °C

The average annual wind speed is 2.5 m / s

Average annual humidity - 73%

Trypillya CHP Energy Generating Enterprise is the largest supplier of electricity in Kyiv, Cherkasy and Zhytomyr regions. The enterprise covers an area of 281.3 hectares, located in the Obukhiv district on the Dnieper coast 45 km south of Kiev, near the village of Trypillya.

After the decommissioning of the Chernobyl NPP, Trypillya TPP with an installed capacity of 1,800 MW is the largest energy generating facility in the Kyiv region.

The main building was built according to the universal project of a pulverized coal thermal power plant with power units with a capacity of 300 MW each.

The main project fuel is Donetsk anthracite, which comes by rail. Reserve, backlight fuel - gas, fuel oil.

The generated electricity from Trypillya comes, first of all, to Kyiv, Zhytomyr and Cherkasy regions.

There is a need for further reconstruction of equipment at Trypillya TPP. Pursuant to the order of the Cabinet of Ministers of Ukraine dated September 8, 2004, PJSC Centerenergo implemented the project of reconstruction of the pulverized coal power unit №2 of Trypillya TPP. The result of the reconstruction was to increase its efficiency, reliability, safety, extend the life of equipment, as well as reduce emissions to European standards.

Reconstruction of the electrostatic precipitator of building 1 "A" of power unit №1 was performed at the power plant, the cleaning efficiency of which is 99%. A significant reduction in the negative environmental impact of the technological process is planned to be achieved through the construction of a full-scale sulfur treatment plant as part of the reconstruction of Unit №2 to reduce the concentration of sulfur oxides in flue gases and remove residual pollution in bag filters. This is the first project of this scale in Ukraine.

TPP is working on the use of secondary raw materials - ash - for the needs of the national economy, for filling roads, manufacturing construction products.

During its operation, Trypillya TPP has accumulated 28 million ash slags, 140 hectares. The projected annual premature death due to emissions from Trypillya TPP, according to Greenpeace, is more than 1,200 people.

### **2.3. Materials and methods of research**

Thermal monitoring of the earth's surface is an important component of geo-ecological monitoring, which provides information on the level of heat load on the natural or urban environment. On the basis of thermal monitoring, it is possible to form various estimates: the dynamics of changes in land use, the effectiveness of urban landscaping, the impact on public health and others.

These surfaces actively accumulate heat during the sunny day, which is given off to the surrounding air during the night, constantly keeping its temperature above the air temperature outside the city, thereby influencing the formation of urban "heat islands". In addition to solar heat storage, there are a large number of man-made objects that generate heat during their activity: cars, poorly insulated heating networks, energy complexes, industrial production.

Currently, the main source of data on the thermal fields of the earth's surface are satellite images obtained in the far infrared range of electromagnetic radiation 8-13 microns. Infrared images of Landsat series satellite systems (5, 7, 8) are now available and distributed free of charge through the web resources of the United States Geological Survey (USGS). The infrared images of the TM and ETM + sensors of the Landsat-5 and Landsat-7 satellites have a spatial resolution of 60 m, and the dual-band images of the TIRS sensor of the Landsat-8 satellite have a spatial resolution of 100 m. with images of other spectral ranges of these satellite systems. To date, only Landsat-8 is active. Landsat-8 is the American remote sensing satellite, the eighth in the Landsat program.

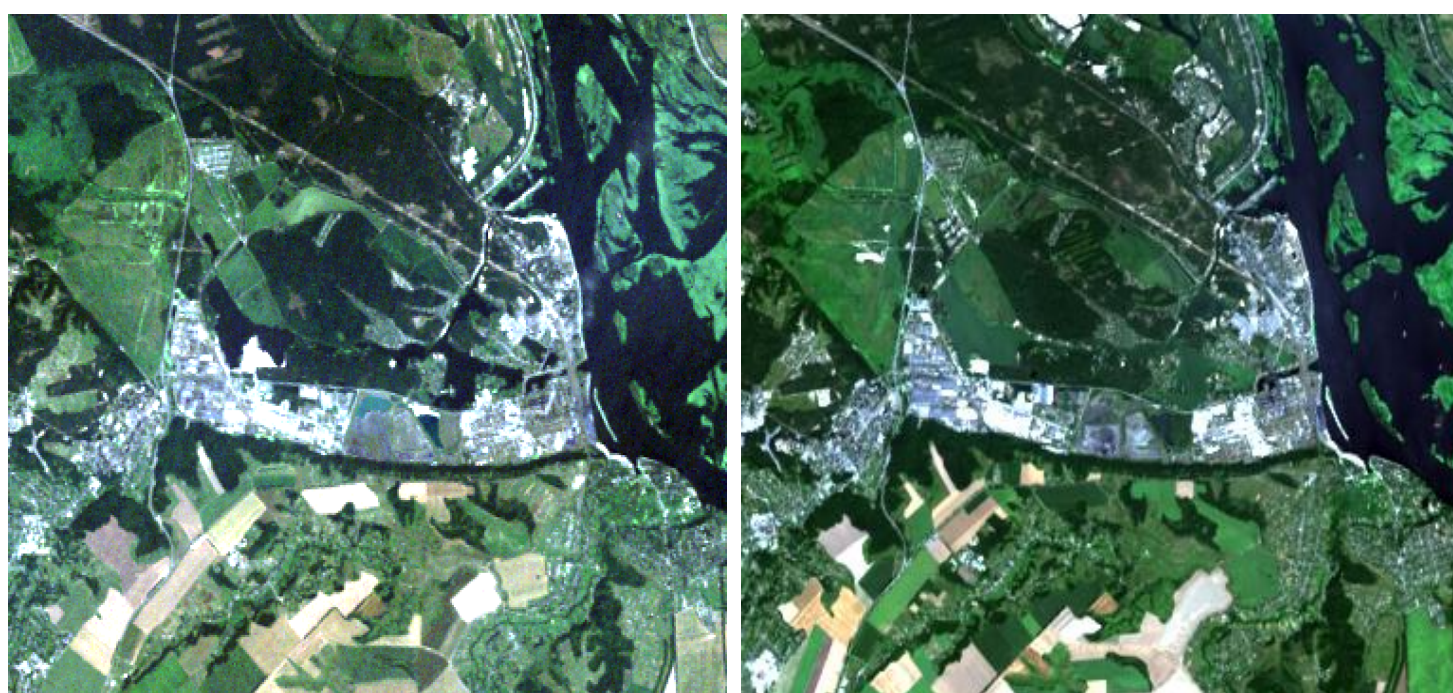
Landsat-8 captures images in the visible wavelength range, near infrared and far infrared, with image resolutions from 15 to 100 meters per point. Land and polar regions are being surveyed. About 400 scenes are shot per day. OLI and TIRS sensors have a higher signal-to-noise ratio (SNR) and allow you to shoot up to 12 bits per point. The operating spectral ranges and calibration constants of the infrared sensors of the Landsat series satellite systems are shown in Table 2.1.



**Operating spectral ranges and calibration constants of infrared sensors of Landsat series satellite systems**

Infrared sensor	Operating spectral range, $\mu\text{m}$	Gain, $W / (m^2 \cdot \mu\text{m} \cdot \text{avg}) / \text{DN}$	Offset (bias), $W / (m^2 \cdot \mu\text{m} \cdot \text{avg})$
TM	6 (10,4 – 12,5)	0,055	1,18243
ETM+	6-1 (10,4 – 12,5)	0,067	-0,06709
	6-2 (10,4 – 12,5)	0,037	3,1628
TIRS	10 (10,6 – 11,19)	0,0003342	0,1
	11 (11,5 - 12,51)	0,0003342	0,1

Fragments of satellite images Landsat-5 and Landsat-8 on the territory of Trypillya TPP, which were used in the study, are shown in Fig. 2.2.



*a)*

*b)*

Fig. 2.2. Fragments of Landsat satellite images for the territory of Trypillya TPP: *a)* Landsat-5 (05.08.2001) and *b)* Landsat-8 (27.07.2021)

The main obstacle to the application of the obtained physical quantities is the effect on infrared radiation of the Earth's atmosphere. Suspended components of atmospheric air, suspended particles, dust, moisture, gaseous impurities reflect, absorb and scatter

electromagnetic radiation. Therefore, for the far infrared range, a large number of models of radiation transmission have been created, which eliminate the influence of the atmosphere on the obtained data.

Sentinel-5P is the first mission of the European Space Agency Copernicus to monitor the atmosphere. The satellite is equipped with a Tropomi sensor to map a number of trace gases, such as nitrogen dioxide, ozone, formaldehyde, sulfur dioxide, methane, carbon monoxide and aerosols.

The goals of the S5P mission are global monitoring of air quality, climate and the ozone layer from 2017 to 2023. The first 6 months of the mission were used for special observations for the commissioning of satellite and tillage systems. The operational phase began in April 2018. Sentinel 5P tracks not only the troposphere, which is the lowest layer of the Earth's atmosphere, but also the stratosphere - the second layer of the atmosphere. The troposphere is very important because we breathe air from this layer of air. Therefore, the study focuses on tropospheric pollutants.

## 2.4 Determination of thermal pollution from thermal power plants according to the Landsat satellite

In order to master the method of working with thermal images, mapping of thermal pollution of anthropogenic origin was carried out. The results of determining the thermal pollution of the Trypillya TPP are shown in Fig. 2.3.

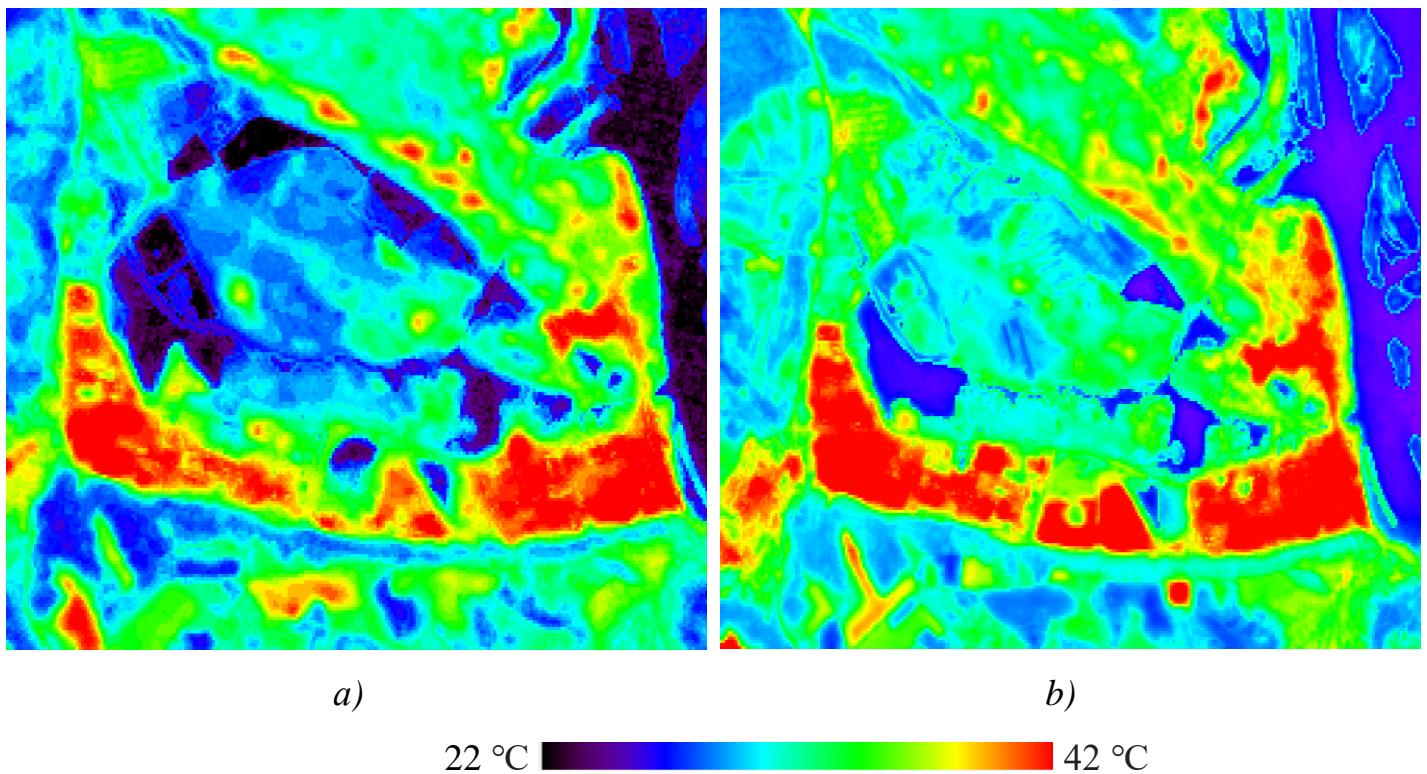


Fig. 2.3 - Temperature field of the territory of Trypillya TPP according to the results of data processing of the Landsat satellite system: a) Landsat-5 August 5, 2001 and b) Landsat-8 July 27, 2021

As we can see from the obtained images, the heat generation around the Trypillya TPP is increased in period from August 5 of 2001 to July 27 of 2021. The dates were chosen because they were the warmest days in the presented years. It gives more understanding to the heating background on the pictures.

The trend of increasing of the temperature is closely connected with extension of sludge fields and power plant at all. New constructed parts of the Power Plant, more asphalted roads and other concrete/iron structures have significant impact on the heat

picture around the station. Because the Thermal Power Plant uses water for cooling and storing of used fuel (sludges), the territory has reservoirs of technician water that can have larger background temperature than other water spots. This water reservoirs haven't exit to other water sources, so they have a large risk to became a still water bogs. Also, the close location of the sludge storage to the Dnieper river creates the problem of water pollution with chemical and physical pollutants.

From the picture: the red one, most heated territory ( $>36$  °C) is the concrete/steel roofs, sludge storages and water reservoirs. The small red dots and lines on the right top of the image in the Ukrainka is roofs from some warehouses or industrial sites. The other background temperature ( $<36$  °C) is the territory, green: Ukrainka city, some agricultural places. The blue one is the water bodies that located on the territory of the Thermal Power Plant.

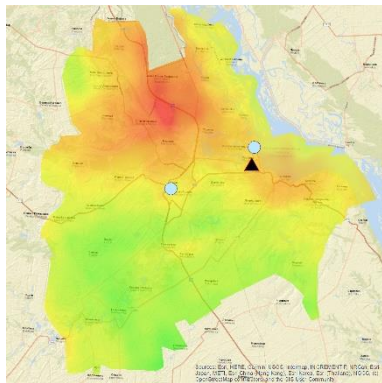
As a result, we can say that this geographic location has a significant impact on the environmental health across this region. Every aspect of ecological purity is touched by Trypillya Thermal Power Plant. Which proves the antiquity of using Power Plants to generate energy and heat for firing houses.

## **2.5 Determination of TPP pollution according to the TROPOMI sensor of the Sentinel-5P satellite**

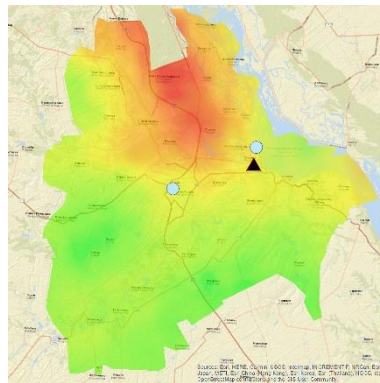
According to the obtained data from the Satellite analysis we have next result:

1. The clear picture of the Ukrainka Thermal Power Plant pollution can't be obtained because of the third-party factors such as changing wind and temperature.
2. The second, and not less important is the pollution from the other sources, such as traffic pollution, industrial and other facility ecological pollution that affects the region of the observation.
3. The obtained data presents the average calculated data from the year of 2021 of the Ukrainka Thermal Power Plant, Obukhiv and Ukrainka towns. It shows the ideal and average number for easy understanding.

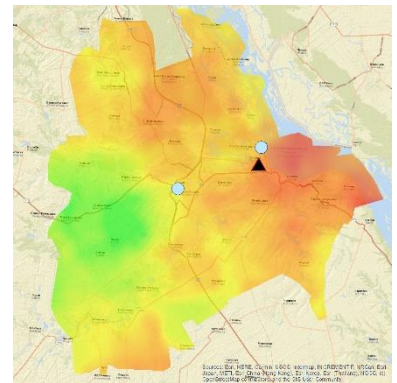
The results of determining the concentrations of pollutants in the air of the study area and their dynamics during 2021 are shown in Fig. 2.4:



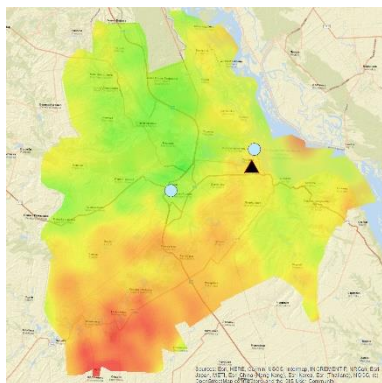
January 2021



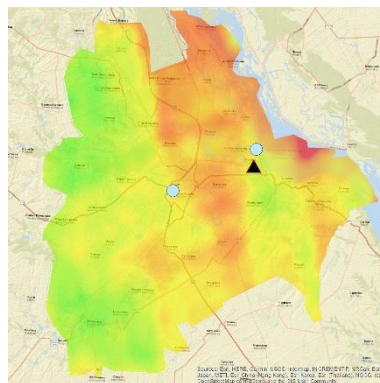
February 2021



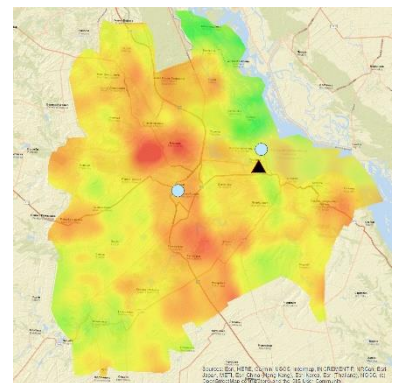
March 2021



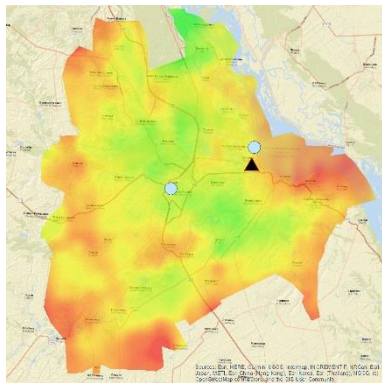
April 2021



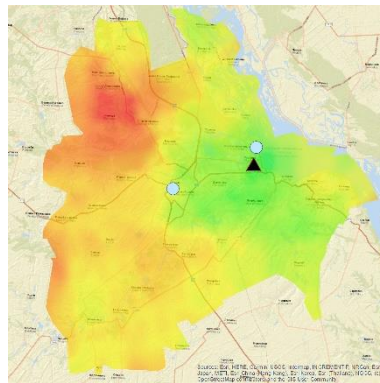
May 2021



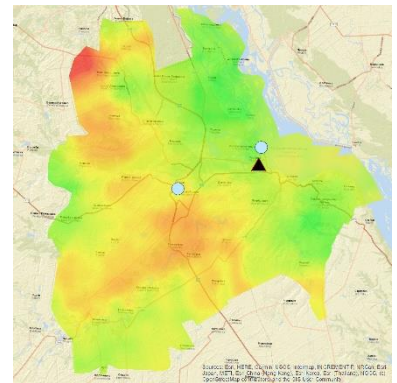
June 2021



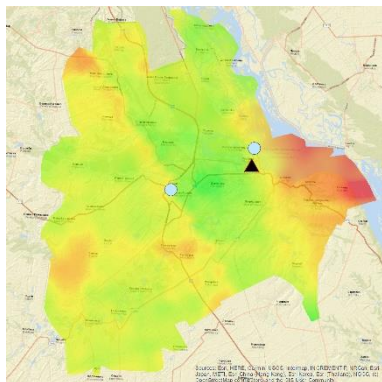
July 2021



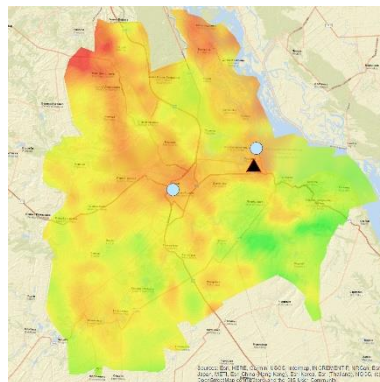
August 2021



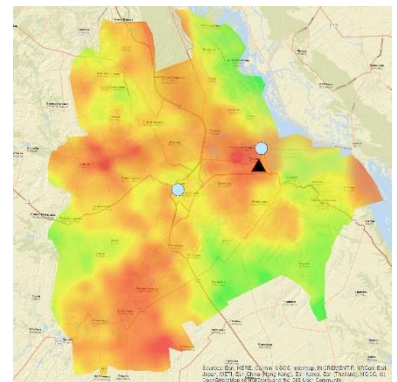
September 2021



October 2021



November 2021



December 2021

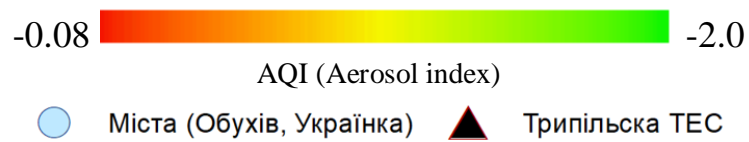
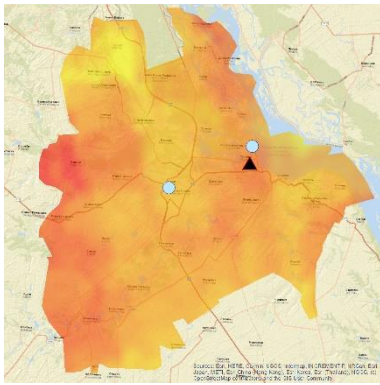


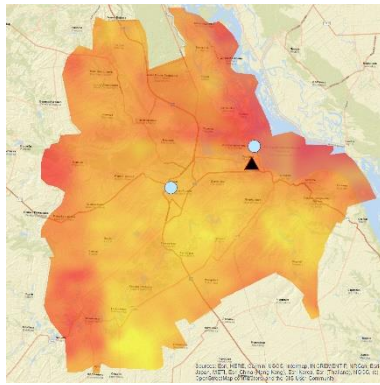
Fig. 2.4 - Spatial distribution of aerosol index values over the study area from January to December 2021.

As we can see from resulted satellite images of the Thermal Power Plant the most polluted air background is during the winter/colder months. It is tightly connected with the working period of the Thermal Power Plant, because it generates heat for houses mainly in the winter months. So, more pollutants enter the atmosphere and can create these clouds of polluted aerosol. In the other non-winter month, the pollution can be created not only by the TPP, it can be created from other industrial or technical facilities that can enter the observation zone even from the other regions because of the moving of wind masses.

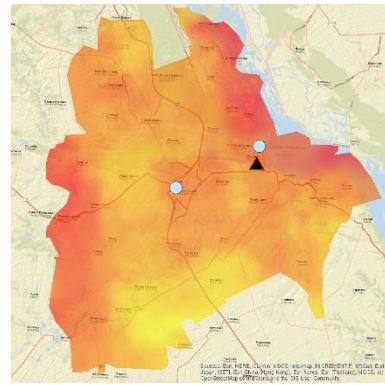
The red level of pollution can highly harm the ecological stance on the territory and isn't normal for permanent existence in the atmosphere of the any region. Other indications are pleased for living, but also have some negative impact.



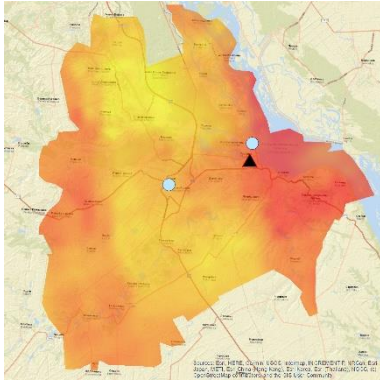
January 2021



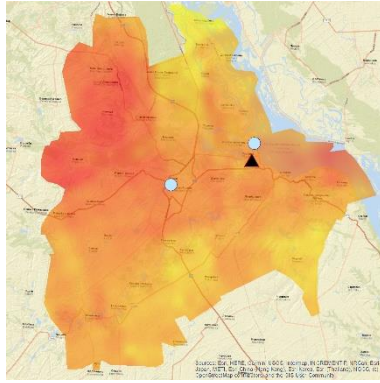
February 2021



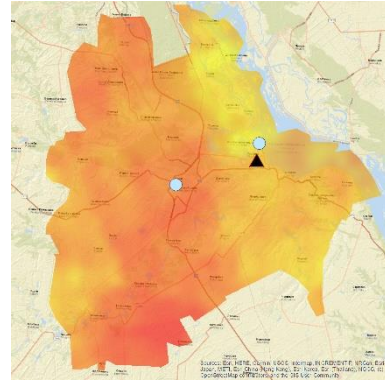
March 2021



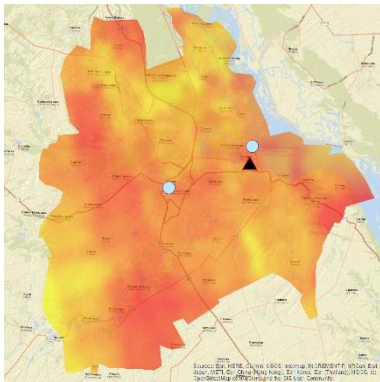
April 2021



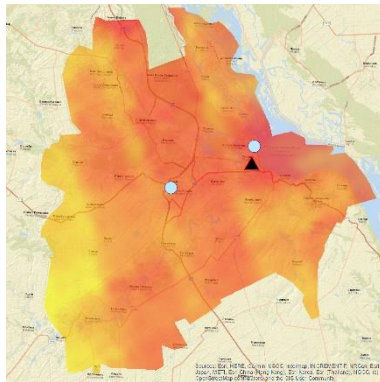
May 2021



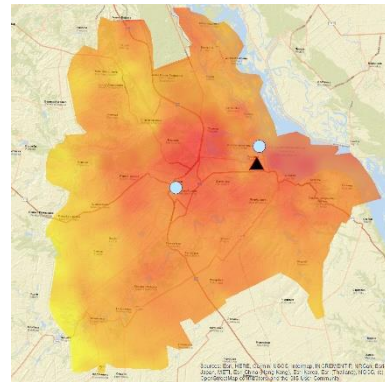
June 2021



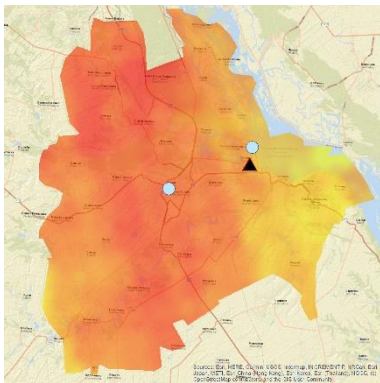
July 2021



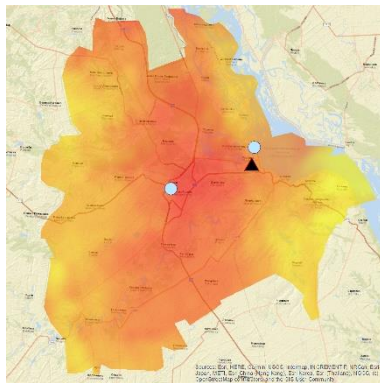
August 2021



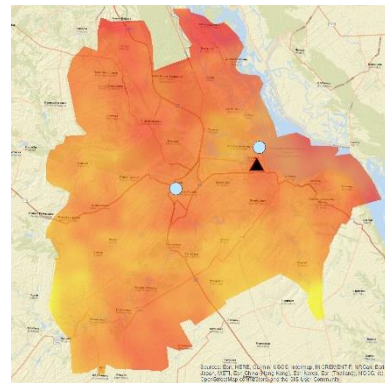
September 2021



October 2021



November 2021



December 2021

0.028  0.041

CO моль/м<sup>2</sup>



Міста (Обухів, Українка)

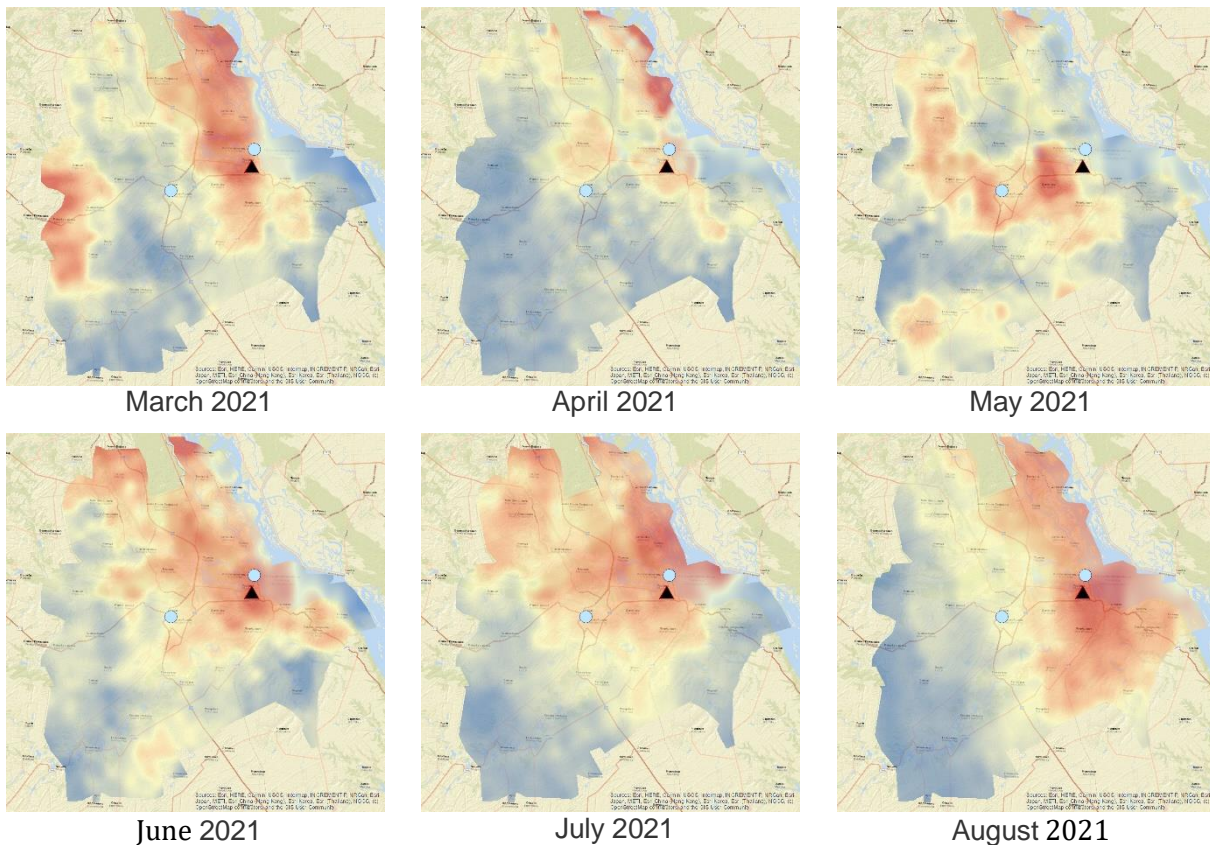


Трипільська ТЕС



Fig. 2.5 - Spatial distribution of carbon monoxide concentration over the study area from January to December 2021.

The given data of the CO pollution shows us that region of the observation during the year have a permanent pollution. That is connected with burning processes that Thermal power plant provides, production of energy and heat using fossil fuels. Also, there are third-party factors that can provide incorrect data during the analysis. For example, car pollution highly affects the results of this analysis part. But we whatever can see the trend that during the warm seasons the level of CO pollution increases. That is because of the ability of gases to spread much better in warm conditions, than in cold.



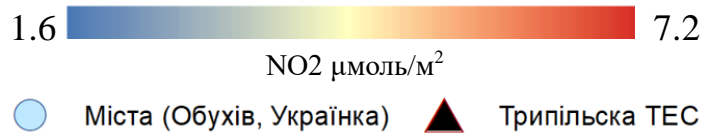
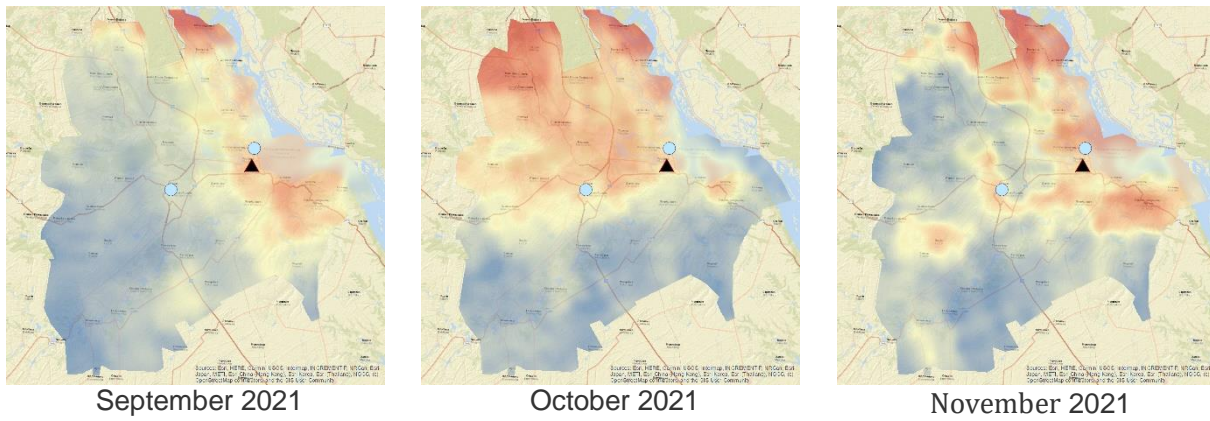
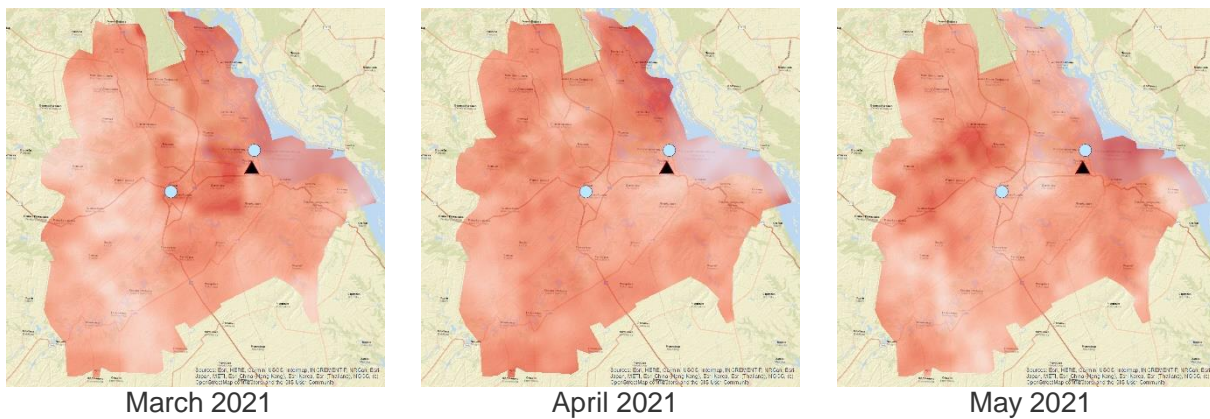


Fig 2.6 - Spatial distribution of nitrogen dioxide concentration over the study area from March to November 2021.

The analysis of NO<sub>2</sub> pollution is conducted from March to November because of the lack of information from the satellite image and there is hard to obtain useful information from it. What conclusion can we make using the presented data? There is a trend of growing NO<sub>2</sub> pollution in the summer and in warm condition period. As we can see from the June to August there are the largest amount of NO<sub>2</sub> pollutant across the observed territory. The pollution of NO<sub>2</sub> is closely connected to the burning of fossil fuels from vehicles, thermal power plants and other industrial sources. So why the level of pollution is that high we can understand.



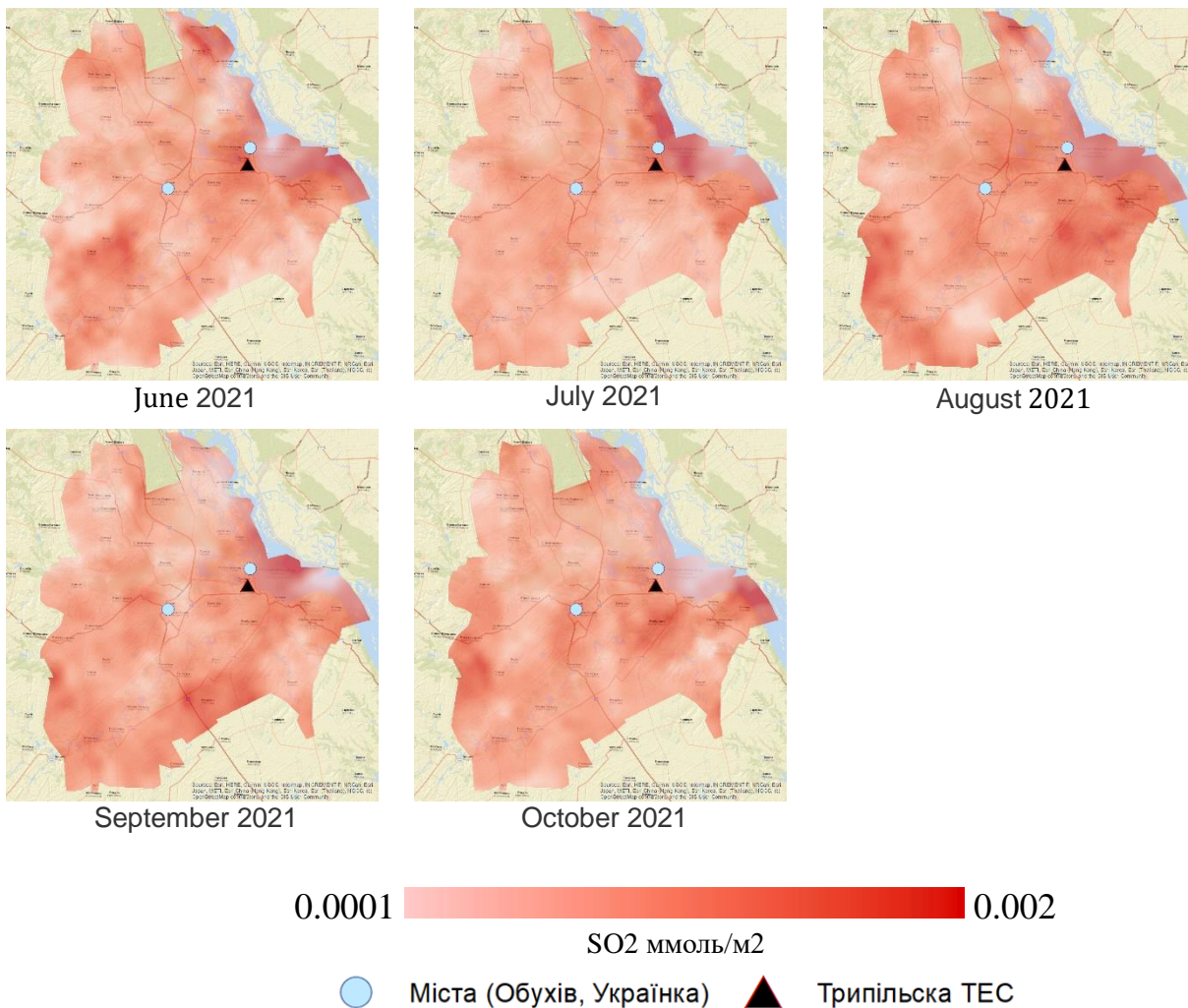
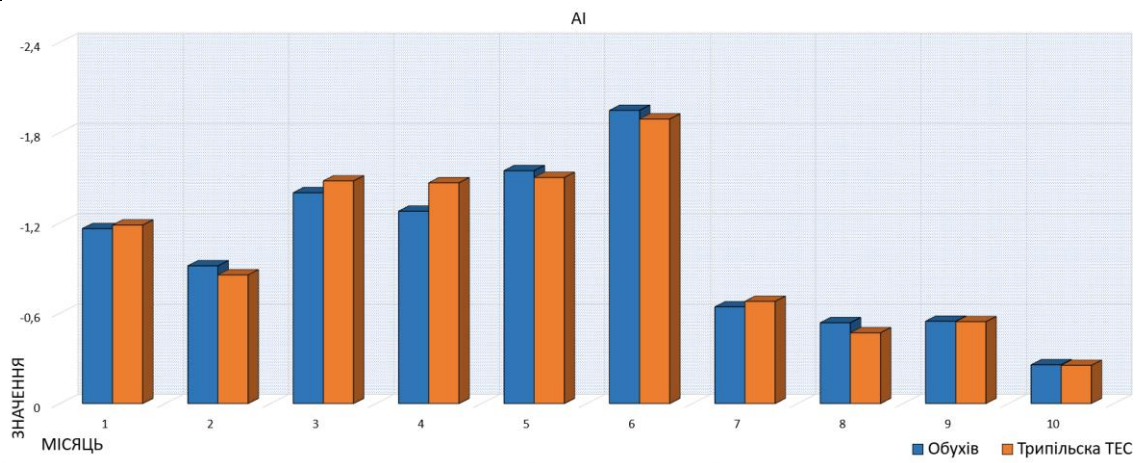
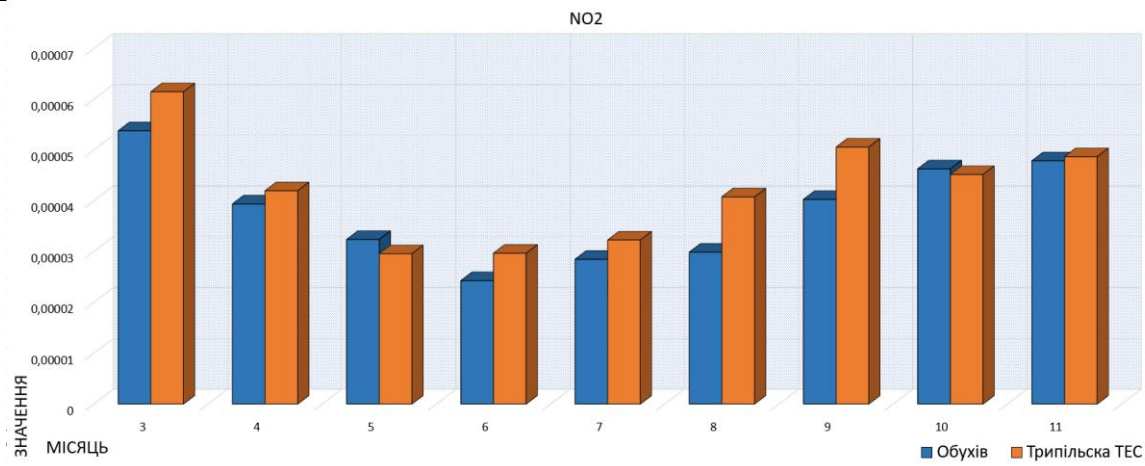


Fig. 2.7 - Spatial distribution of sulfur dioxide concentration over the study area from March to October 2021.

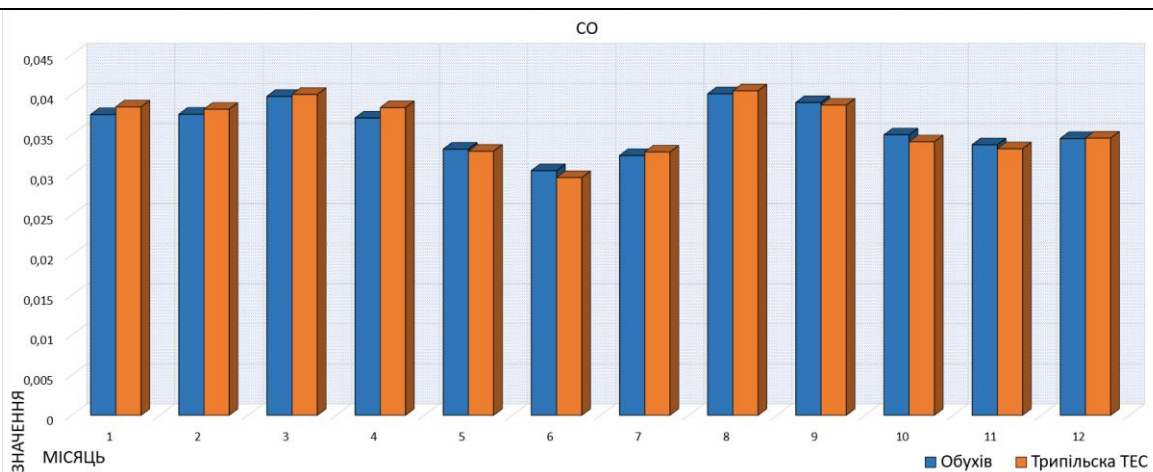
The data represented from March to October because of lack of good quality images. The images give us a view on the permanent SO<sub>2</sub> pollution in the research area. That is again connect to the specification of the observed enterprise. The SO<sub>2</sub> emission is the attribute of the Thermal Power Plants. Fossil fuel burning, vehicles and smelting facilities have significant influence on the emission of this gaseous pollutant. SO<sub>2</sub> is the most common pollutant in the world. That gives us a sign that thermal energetics and vehicles are the main ecological problems of our time.



a) AQI



b) NO<sub>2</sub> µmole/m<sup>2</sup>



c) CO mole/m<sup>2</sup>

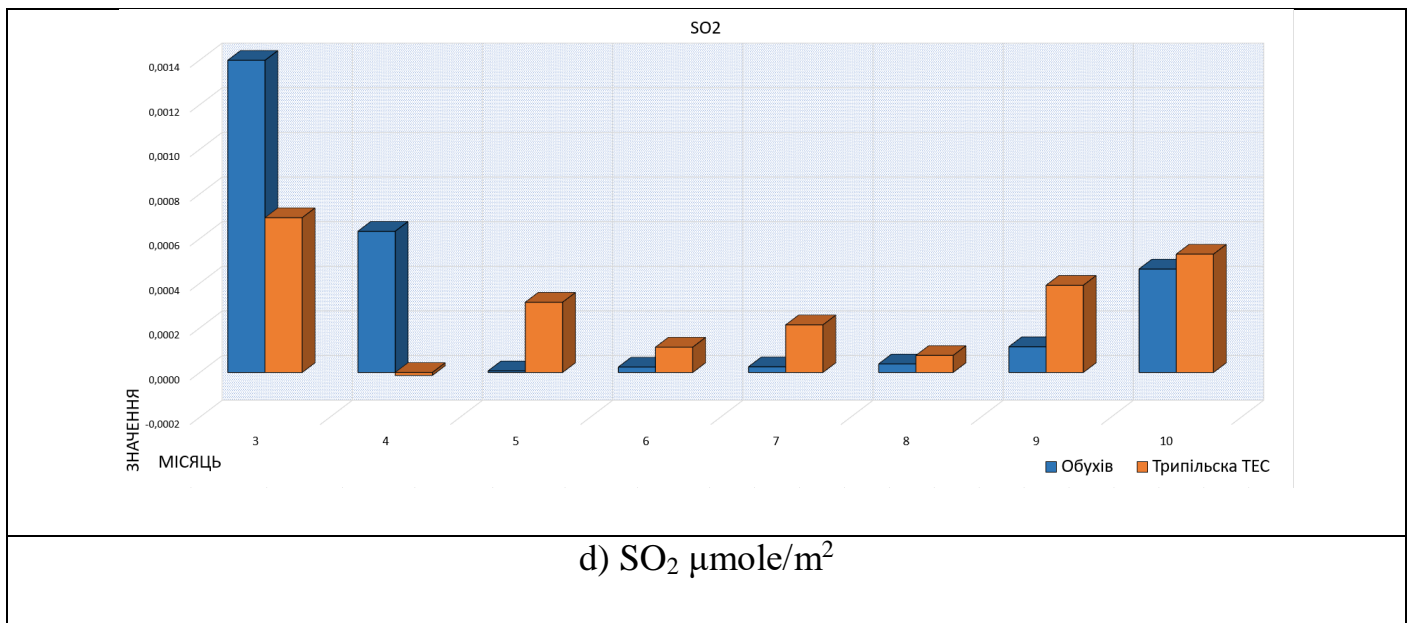


Fig. 2.8 – the comparison between Trypillya TPP and Obukhiv city by their pollutant concentration.

a) The presented bar chart shows its apex during the warmest, summer period. As we know gases has ability to diffusion (non-equilibrium process of moving a substance from an area of high concentration to an area of low concentration, leading to spontaneous equalization of concentrations throughout the occupied volume).

b) The NO<sub>2</sub> pollution on Trypillya TPP and Obukhiv city are nearly the same, but mostly the exhaust from the enterprise is larger.

c) The CO level are nearly the same on two observation points.

d) SO<sub>2</sub> parameter shows us that during the March and April months the level of pollution in Obukhiv city beat its normal stance and hits it`s larger parameter. During the year the SO<sub>2</sub> pollution on the territory of enterprise is larger.

In the conditions of Ukraine for the busiest daily schedule of winter day load is usually characterized by two peaks - evening and morning - and two dips - deeper than night and day.

In different countries, the ratio of the minimum (baseline) load in the daily schedule to the maximum (peak) on average varies from 0.6 to 0.8.

In integrated power systems, the load schedule usually becomes denser and a relative reduction in maximum load is achieved, especially if the power systems are in different time zones.

Annual load schedules of energy systems depending on climatic and socio-economic conditions are characterized by:

- reduction of workload in the summer months (mainly due to the reduction of utility load), which is typical for Western Europe, Russia, Ukraine;
- increasing the load in the summer months in countries with hot climates (due to increasing household loads, irrigation, etc.).

## **2.6 Conclusion to the chapter 2**

After the determination, analyzing and mapping of pollution data near the Trypillya Power Plant by a satellite survey we can say that:

1. Remote sensing methods can dramatically increase the quality and speed of monitoring of special regions and territories.
2. The main problem of the Trypillya Power Plant is the lack of equipment reconstruction and its development.
3. Landsat 8 is an easy and useful tool for observation of the territory
4. Humanmade structures that was constructed with metal and concrete generates a large amount of heat that have a large impact on the ecological state of the region.
5. As we can see from the presented observation by the Tropomi Sensor pollution across the researched territory is permanent. Mainly the pollutants are concentrated across the territory of the Trypillya TPP.

## CONCLUSIONS

As a result of the analysis of air pollution by remote sensing of the territories around the Trypillya thermal power plant, graphs of emissions of major pollutants, maps of thermal pollution and maps of the spatial distribution of CO, NO<sub>2</sub> and SO<sub>2</sub> were constructed.

A comprehensive analysis of thermal pollution of Trypillya TPP, as well as annual dynamics of concentrations of carbon monoxide, sulfur dioxide, nitrogen dioxide was conducted to study the air quality of Obukhiv district of Kyiv region and inform interested united urban communities.

The Thermal Power Plants is large scale problem not only on the territory of Obukhiv region, but everywhere across the world. Theirs main problem is a bad connection with Main Worldwide Development Goals and environment health itself. TPPs are outlived their time and needs be removed at all or to be under control that satellites can easily provide.

The main objectives of the work were successfully achieved.

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