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COMPREHENSIVE STUDY OF ATMOSPHERIC POLLUTION IN CITIES

Assessment of air pollution level of Poltava is performed by using statistical data of enterprises inventory, stationary sites and results of calculations by program EOL-2000. Assessment and correlation the results by new researches (bioindication, air pollution indexes) according to the standards of Ukraine and the world ones are performed. The possibility of performance the further project for an impact of technology-related air pollution on the environment and human health is proved. Implementation of GIS for monitoring the air pollution of Poltava is proposed. This system can be used as a model of such GIS for other similar cities. The process of occurrence of the heat-island affect over cities and its influence on the atmospheric component is described. The importance and efficiency of the comprehensive study of atmospheric air pollution in cities are proved.

***Keywords:** atmosphere, methods of analysis, EOL 2000, pollution index, GIS technology, heat-island effect.*

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КОМПЛЕКСНЕ ДОСЛІДЖЕННЯ ЗАБРУДНЕННЯ АТМОСФЕРИ В МІСТАХ

Виконано оцінювання рівня забруднення атмосферного повітря міста Полтави за допомогою статистичних даних інвентаризацій підприємств, стаціонарних постів спостереження та результатів розрахунків програми ЕОЛ-2000. Здійснено оцінювання й кореляцію отриманих результатів новими методами (біоіндикація, індекси забруднення атмосфери) згідно зі стандартами України та світу. Доведено можливість виконання подальшого прогнозування впливу техногенного забруднення атмосфери на навколишнє середовище й здоров'я людей. Запропоновано впровадження географічної інформаційної системи спостереження (ГІС) за забрудненням атмосферного повітря міста Полтави, модель якої може бути використана для моделювання подібних ГІС і для інших міст. Описано процес виникнення острова тепла над містами та його вплив на атмосферну складову. Доведено важливість та ефективність комплексного дослідження стану забруднення атмосферного повітря міст.

***Ключові слова:** атмосфера, методи аналізу, ЕОЛ-2000, індекси забруднення, ГІС-технології, острів тепла.*

Introduction. The topic of the atmospheric air quality of always remains relevant since the environment general condition and, most importantly, the health of the inhabitants depends on the city air state. Its importance is determined in the national policy of Ukraine and enshrined in the Law of Ukraine «On the main principles (strategy) of the state environmental policy of Ukraine for the period up to 2020» [1].

Review of the latest research sources and publications. For the formation of the atmospheric air pollution state integrated assessment theory reliability were studied and used as own scientific worked [2, 3], and the works of other scientists. Specifically, publications [4] and [5] it is the application of GIS technology in research environment and atmosphere in particular. Resource [6] and [7] provide information on bioindicating the environment state. In source [8] air quality indexes for many pollutants have been established. One of such methods combination goal in a comprehensive assessment is verifying the compliance of the obtained results to primarily acts and directives on air quality of the city, the main of which can be found in the source [9].

Definition of unsolved aspects of the problem. Despite a sufficient number of methods for studying the environment there are some unresolved issues. One of them is choosing the number of research methods that can be used to give a full picture of the air state while ensuring financial, resource and time efficiency.

Problem statement. The aim of the project is the research of air pollution level in the cities with a population of about 250 – 350 thousand people by using complex assessment and with the possibility of further forecasting of the technology-related air pollution influence on environment and human health.

Main goals are: 1) analysis of atmospheric pollution from stationary and mobile sources; 2) experimental research by bioindication methods; 3) calculation of atmospheric pollution indices; 4) development of GIS for analysis of previous data and further forecasting; 5) improving the city ventilation and the urban heat-island effect.

Basic material and results. In modern conditions, systematic monitoring of air pollution level in Poltava is carried out 24 hours a day at 4 stationary posts of surveillance «POST-2A». Sampling for contamination with harmful impurities is carried out four times a day with 10 ingredients, except for dust, soluble sulfates, and carbon monoxide. Characteristics of atmospheric air pollution in the city according to stationary posts of surveillance are given in Table 1. Some indexes of atmosphere pollution by individual contaminants in the areas of Poltava were calculated basing on the data of statistical reporting 2-TP Air and materials of inventory sources of pollutant emissions [2].

Table 1 – Characteristics of air pollution in Poltava (mg/m^3)

Impurities	MAC	Average concentration		Maximum concentration	
		2015	2016	2015	2016
Dust	0,15	0,2	1,3	0,9	1,8
Sulfur dioxide	0,05	0,004	0,08	0,019	0,05
Carbon dioxide	3,0	2	0,7	9	1,8
Nitrogen dioxide	0,04	0,035	0,98	0,19	1,25
Nitrogen oxide	0,06	0,025	0,46	0,11	0,3
Hydrofluoric acid	0,005	0,002	0,3	0,017	0,6
Hydrochloric acid	0,2	0,02	0,09	0,11	0,45
Hydrogen nitride	0,4	0,01	0,3	0,08	0,35
Formaldehyde	0,003	0,003	1,14	0,068	1,5

According to preliminary calculations of the atmospheric air pollution index by the individual pollutants for the Poltava arias, it can be proved that the atmospheric air of each district and the city as a whole is conditionally clean. Since the integrated air pollution index set by calculation is ranged from 1.3 to 2.61, which is much less than the norm, that is 5. In this case, the class of the ecological state of the atmosphere is defined as normal, this is a low level of pollution, which affects at the overall level of city air pollution not much and, as a result, does not significantly affect at the inhabitant health and their working capacity.

Within the framework of the topic, the analysis of the pollution level is carried out on the basis of pollutants dispersion calculations in the atmosphere surface layer under the program EOL-2000 [h] for 195 enterprises of the city, which represents 3,686 emission sources. The total number of identified pollutants is 196 [3]. On the basis of the calculation obtained results, the program EOL-2000 [h] compiled maps of pollutants dispersion in the surface layer of the atmosphere separately for administrative areas of the city (Fig. 1).

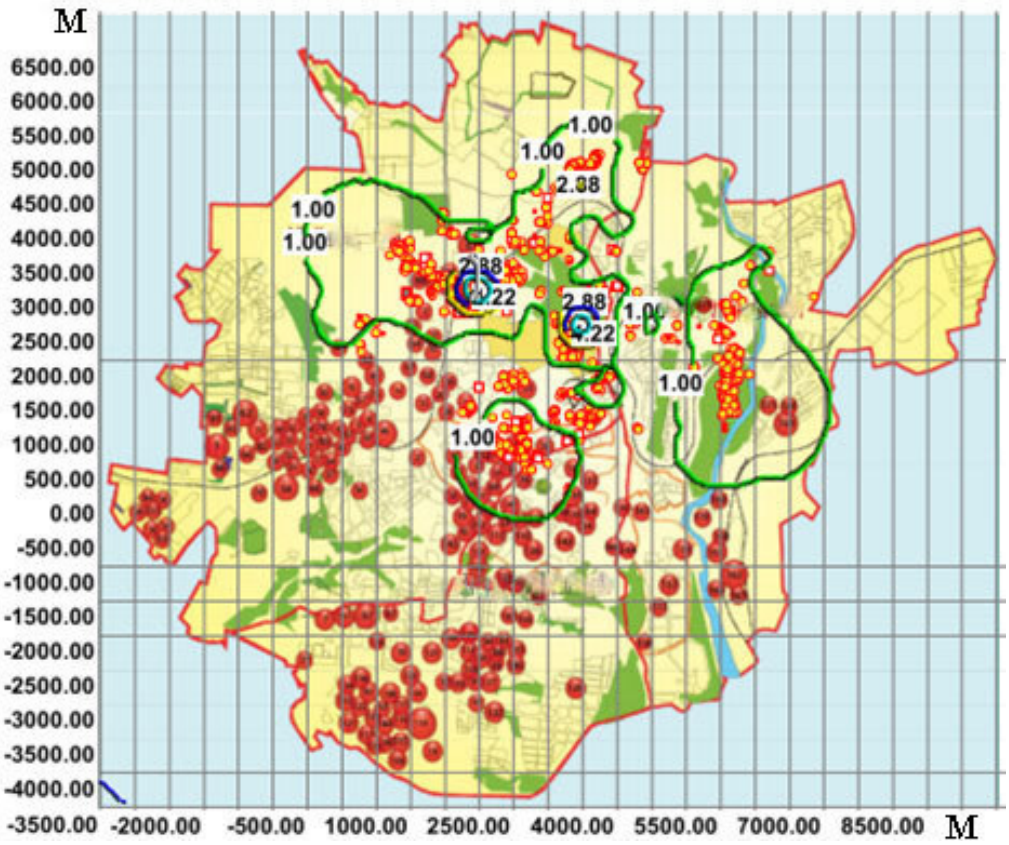

Figure 1 – Dispersion map of nitrogen oxide (IV) in Poltava

Another method of the comprehensive assessment of Poltava air state in the future is bioindication use. Environmental factors affect certain plant species very strictly [10]. Thus, there can be used the inverse pattern and considered the impact of the physical environment on plants. For example, lichenindication (determination by lichen), briodinduction (using moss) and mycoindication (using fungi) can be used to determine air pollution level.

The city sustainable development ecological dimension indexwhich is based on three categories: «Ecological systems and natural resources», «Anthropogenic pressure on the environment», «Municipal ecological management», is an important indicator of such comprehensive assessment of the city air environment. [11]. It contains 28 indicators of city sustainable development and 89 indexes.

For this research, it is planned to use two indicators: «air quality», which consists of seven parameters (quantitative indexes of characteristic pollutants), and «emissions to atmospheric air», which contains two parameters (emissions of pollutants into the atmospheric air per 1 km^2 and per person).

The protection of the atmosphere cannot be successful if it applies only measures directed against certain pollution sources. The best results can only be obtained through objective approach to determining the causes of air pollution, the contribution of individual enterprises, sources and determining the real possibilities of limiting these emissions. Therefore, the final stage of the conducted assessment is the creation of geo-information technology for the atmosphere protection. Its task is interwoven with the government information and analytical system of Ukraine emergency situations, developed by the order of the Ministry for Emergencies in Ukraine by specialists and scientists of the Distributed Information and Analytical Center of INTEK-Ukraine, the Institute of Cybernetics of the National Academy of Sciences of Ukraine, the Institute of Geochemistry of the National Academy of Sciences and the Ministry of Emergencies of Ukraine, NDC technologies of sustainable development of the Taurian National Vernadskuy University and CJSC «ECOMM Co.», which aims are to provide interagency information interaction and analytical support for decision-making on the basis of modern spatial analysis methods, simulation of emergency situations development and forecasting their consequences [12].

Thus, using the GIS toolkit, a program package (an example of their use is shown in Figure 2) allows calculating and visualizing the results of modeling the pollutants emission into the atmosphere, considering all inventory data of enterprises, with the possibility of their correction and forecasting under changing different indicators.

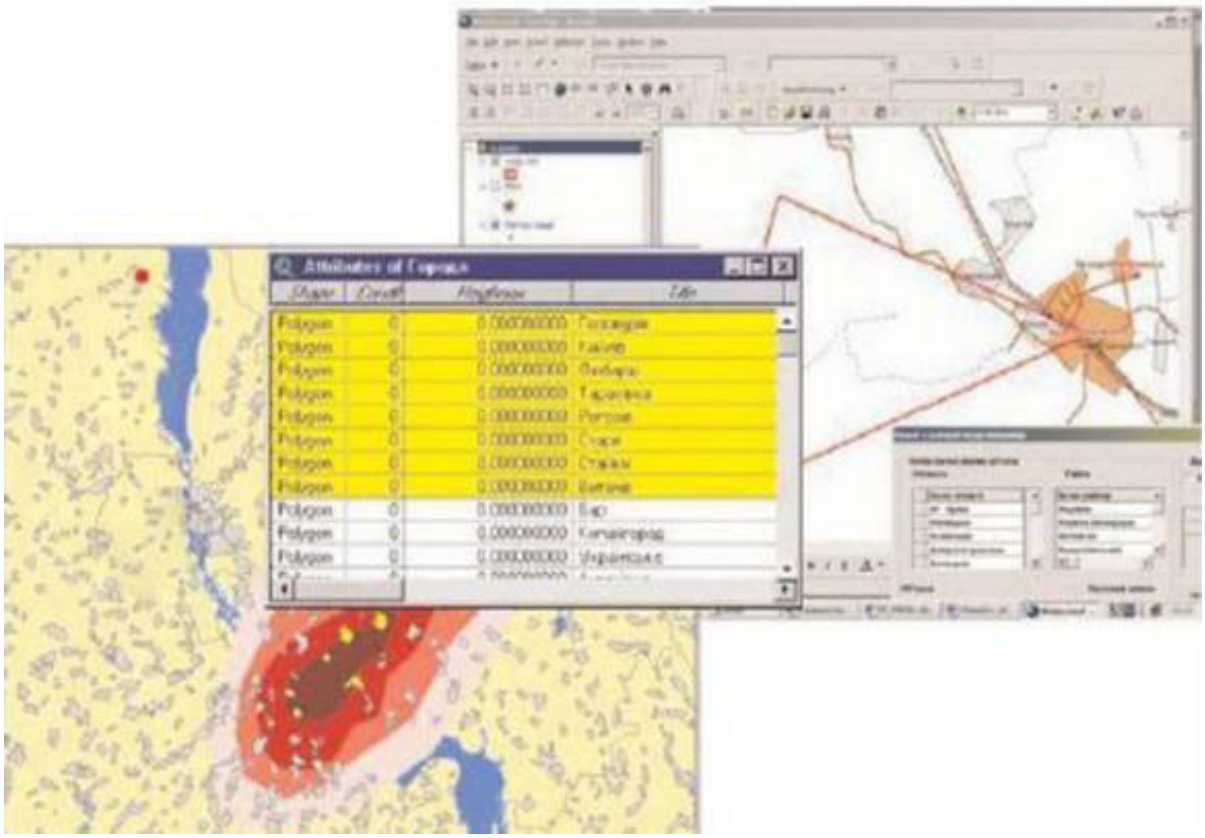

Figure 2 – Modeling results visualization of the pollutants emission in the atmosphere using the GIS toolkit

The air temperature is most strongly influenced by the territory urbanization and is one of the most measurable meteorological parameters. The temperature differs between the urbanized area and the surrounding undeveloped or poorly developed landscapes depending on a number of factors. Among them there are the city size, its territory construction density and the synoptic conditions, the weather conditions at a given time.

One of the most significant features of the urban climate is the appearance in the city of the so-called «heat-island effect», which is characterized by higher air temperatures than in the countryside (Fig. 3). This phenomenon is the result of several reasons.

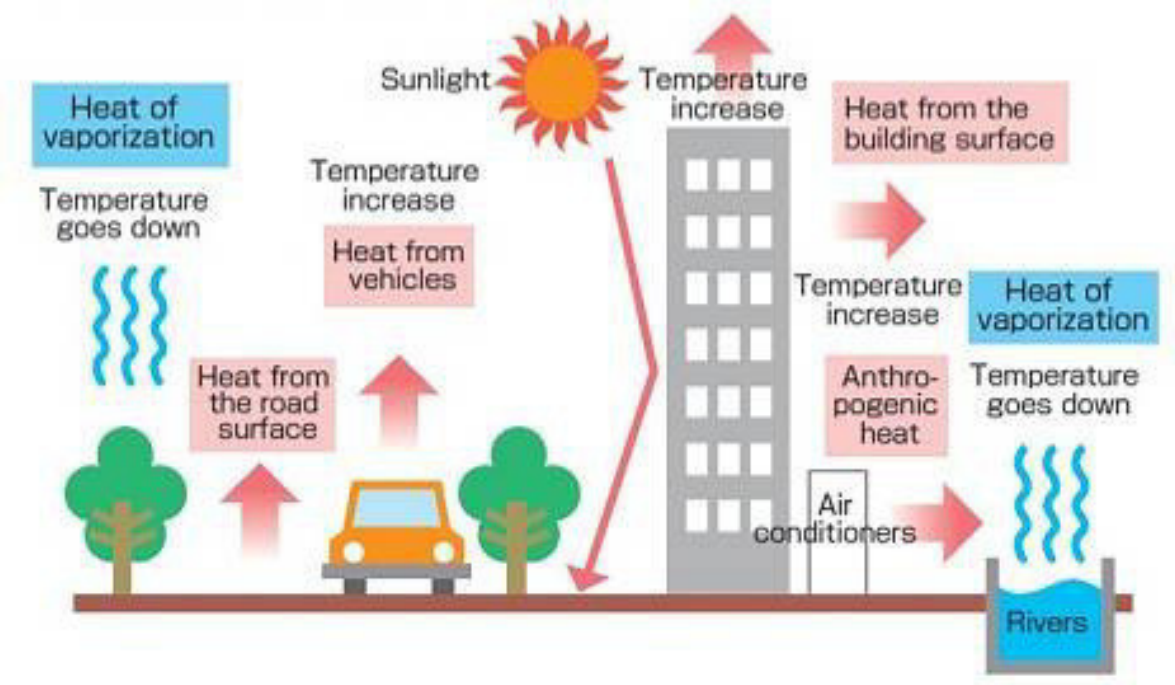

Figure 3 – How the «heat-island effect» occurs

First, in cities, the albedo of the underlying surface is reduced due to the appearance of its buildings, structures, artificial coverings. Reduction of the albedo as a result of the territory development leads to more intensive absorption of solar radiation in comparison with unoccupied areas, the accumulation of the heat absorbed by the day in the construction of buildings and structures, and its release into the atmosphere in the evening and night hours. In addition, in urbanized areas, the heat consumption for evaporation is sharply reduced by reducing areas with open soil cover and occupied by green plantations, and the rapid removal of atmospheric precipitation by rainwater systems does not allow the creation of moisture reserve in soils and surface water bodies. Urban development also leads to the formation of air stagnation zones, at low wind speeds, prevents turbulent mixing of the atmosphere surface layer and hears transfer to its overlying layers. Consequently, the building heat transfers due to the conditions deterioration of turbulent mixing in the surface layer decrease in comparison with the undeveloped territories and the heat builds up inside the building causing it to overheat.

Secondly, the formation of the «heat-island effect» in the city territory is facilitated by change in the atmosphere transparency. Various impurities from enterprises and transport coming into the atmosphere lead to a significant decrease in the total solar radiation. But, even more, they reduce the counter infrared radiation from the earth surface, which in combination with the heat transfer of buildings and industrial facilities leads to the appearance of a local greenhouse effect and the development of temperature anomalies in the city.

Most strikingly, the contrast of the city-suburbs temperature appears when it is clear and not windy and disappears when it is windy and cloudy. In the evening and at the first hours after sunset, due to the peculiarities of the heat-island effect formation, the temperature contrast is sharper than at noon, and in summer it appears better than in winter with similar synoptic situations.

The average air temperature in the big city is usually above the temperature of the surrounding areas at 1 – 2°C; however at night, with a slight wind, the temperature difference can reach 6 – 8°C. Over the centers of large cities, the «heat-island effect» rises to 100 – 150 m, and in cities of smaller sizes – 30 – 40 m (Fig. 4).

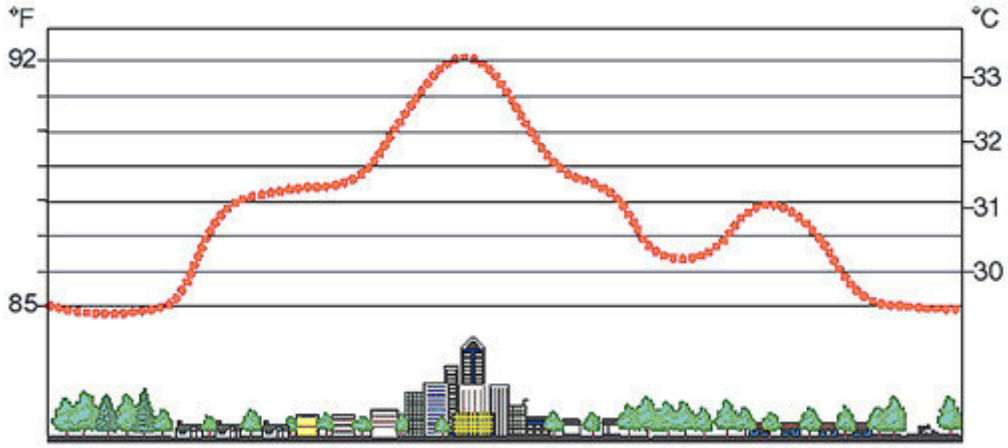

Figure 4 – Section of the «heat-island effect» over the city

The formation of a «heat-island effect» in built-up areas has a number of direct or indirect environmental and bioclimatic effects, which can have both positive and negative character.

Ecological consequences of the «heat-island effect»:

– «displacement of the city» by its climatic characteristics in the southern direction: the frost-free and snowless periods in the city territory increase, the earlier onset of the growing season;

– increase in the number of days with thaws. In the cold half-year, the transition of air temperature through 0 ° C creates problems not only for economic and road maintenance services of the city but also for the state of its natural environment components, primarily green vegetation [13].

Therefore, it is very important for the comprehensive assessment of atmospheric air to consider these factors.

Conclusions. The performed analysis and assessment the atmosphere state allow for objective forecasting, planning and further development of the atmospheric air protection program in Poltava as part of the regional target program of environmental protection, rational use of natural resources and ensuring environmental safety considering the regional priorities of Poltava region for 2017 – 2021 years. The methodology of such an integrated approach to the assessment of atmospheric air pollution with the confirmatory results of its relevance and perspective can be used by other cities not only in Ukraine but also in the practice of foreign settlements. It is especially right choice for cities with a population of about 250 – 350 thousand people.

Therefore, the choice of the most effective comprehensive analysis for the research of the atmospheric air pollution state in Poltava is relevant and promising in view of improving the emissions control level from stationary and, in the long term, pollution mobile sources and, as a result, city air quality improving.

References

1. *Регіональна програма охорони довкілля, раціонального використання природних ресурсів та забезпечення екологічної безпеки з урахуванням регіональних пріоритетів Полтавської області на 2012 – 2015 роки (програма «Довкілля – 2015»). – Полтава, 2011. – 150 с.*
2. *Максюта Н. С. Аналіз стану забруднення атмосферного повітря м. Полтави / Н. С. Максюта, Ю. С. Голік // Збірник статей IX Міжн. наук.-практ. конф. « Еколого-правові та економічні аспекти екологічної безпеки регіонів». – Харків, 2014. – С. 85 – 88.*
3. *Максюта Н. С. Стан атмосферного повітря міста Полтави / Н. С. Максюта, Ю. С. Голік // Збірник тез доповідей Міжн. наук.-практ. конф. «Проблеми екологічної безпеки». – Кременчук, 2014. – С. 26.*
4. *Світличний О. О. Основи геоінформатики / О. О. Світличний, С. В. Плотницький. – Суми: ВТД «Університетська книга», 2006. – 295 с.*
5. *Ночвай В. Використання ГІС у задачах управління якістю повітря / В. Ночвай, Р. Криваковська, О. Іщук // Електроніка та інформаційні технології. – 2012. – Вип. 2. – С. 154 – 163.*
   ISSN 2224-087X
6. *Димитрова Л. В. Епіфітні лишайники та мохоподібні як індикатори стану атмосферного повітря міста Києва: автореферат на здобуття наук. ступеня канд. біол. наук. за спец. 03.00.16 – екологія / Л. В. Димитрова. – Київ: КНУ, 2009. – 21 с.*
7. *Яковишина Т. Ф. Біоіндикація забруднення атмосферного повітря примагістральної території [Електронний ресурс] / Т. Ф. Яковишина, К. О. Чорнобук. – Режим доступу: http://www.rusnauka.com/5_PNW_2010/Ecologia/59319.doc.htm*
8. *Vicenta A. B. Assessment of PM10 pollution episodes in ceramic cluster (NE Spain): proposal of a new quality index for PM10, As, Cd, Ni and Pb. / A. B. Vicenta, T. Sanfeliu, M. M. Jordan // Journal of environmental management. – London: Academoc Press, 2012. – V. 108. – P. 92 – 101.*
   DOI: 10.1016/j.jenvman.2012.04.032
9. *Якість атмосферного повітря: короткий опис Директив ЄС та графіку їх впровадження – Проект ЄС «Додаткова підтримка Міністерства екології та природних ресурсів України у впровадженні Секторальної бюджетної підтримки». – Київ, ЄС, 2015. – 9 с.*
10. *Біоіндикація як метод оцінки стану навколишнього середовища [Електронний ресурс]. – Режим доступу: http://edportal.net/referaty/ekologiya/230948/.*
11. *Лотиш О. Л. Система екологічних індикаторів сталого розвитку міста як інструмент оцінювання ефективності муніципального екологічного менеджменту [Електронний ресурс] / О. Л. Лотиш // Електронне наукове фахове видання «Ефективна економіка» – Дніпропетровський державний аграрно-економічний університет. – Режим доступу: http://www.economy.nayka.com.ua/?op=1&z=2191.*
12. *Мокін В. Б. Геоінформаційні системи в екології / В. Б. Мокін, Є. М. Крижанівський. – Вінниця, 2014. – 192 с.*
13. *Литвенкова И. А. Микроклимат городской среды. Образование «острова тепла» [Электронный ресурс] / И. А. Литвенкова // Экология городской среды: урбоэкология. – Режим доступа: http://ekolog.org/books/42/3_2.htm*