

CADASTRE AND LAND MONITORING

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RESEARCH OF SPATIAL LOCATION SANITARY PROTECTION ZONES OF INDUSTRIAL ENTERPRISES USING METHODS OF GEOINFORMATION MODELING

The problem of applying thematic mapping of production facilities in order to obtain spatial data about the harmful effects on the environment is relevant. One of the factors that minimizes this impact is the observance of sanitary protection zones. Areas designated for sanitary protection zones must correspond to current data, which can be modeled by modern GIS technology using remote sensing data of the Earth, which will allow you to quickly and accurately obtain spatial characteristics of objects and analyze thematic information. Therefore, the aim of the work is to obtain and to analyze spatial thematic data on sanitary protection zones of industrial enterprises. Methods. For the spatial analysis of sanitary protection zones the method of modeling of spatial data using cartographic and remote sensing data and the analysis of the constructed model are applied. Results. A cartographic model was created and compliance with sanitary protection zones by industrial enterprises of Slavuta and Khmelnytsky nuclear power plant was analyzed. Scientific novelty and practical relevance. It consists in the complex application of cartographic and remote sensing data for modeling and analysis of the location of sanitary protection zones of enterprises in the city of Slavuta. The obtained thematic geospatial data can serve to eliminate the shortcomings of planning and development of both enterprises and the surrounding infrastructure. The analysis of the results showed an unsatisfactory state of compliance to requirements of sanitary protection zones by industrial enterprises in Slavuta. The tested workflow can be used for modeling and analysis of sanitary protection zones of enterprises that have a harmful effect on the environment, which will increase the level of control in the field of sanitary legislation using GIS technologies.

Key words: thematic mapping; map updates; remote sensing data of the Earth; sanitary protection zone; GIS technologies, ArcGIS.

Introduction

The growing needs of the world's population in energy carriers, industrial and food products lead to an increase in industrial enterprises and building their capacity. Enterprises by their work provoke industrial emissions into the environment, which, of course, does not change its condition for the better.

To prevent the harmful effects of industrial facilities on human, animal and nature life, laws have been passed to preserve the environment and reduce its destructive effects. In Ukraine, such a law is the law "On approval of the State sanitary rules (SSR) of planning and development of settlements" (SSR 173-96) [On approval of the State..., 1996]. In particular, the law contains requirements for the location of sanitary protection

zones (SPZ) around enterprises, namely: their size, method of determination, permissible and inadmissible construction sites on this land parcel. According to sanitary rules, a sanitary protection zone is an area that is specially designated to reduce the level of harmful effects on the environment.

The issue of damage from enterprises to the environment is considered in the paper (Kharkova, Chugai, 2018), in which the authors, using the data of Main Department of Statistics, assess the danger of industrial facilities located in the Mykolaiv region. The paper [Musienko, 2010] examines in detail the design of SPZ on the basis of existing cartographic data by constructing buffer zones in GIS. The analysis of SPZ of already existing enterprises in Vinnytsia was performed by the graphoanalytical method on the city plan [Druzhynin & Pleshkanovska, 2015]. The

example of the work [Makarenko, & Budak, 2017] shows how the inspection of compliance with sanitary protection standards is performed on the example of a landfill. To do this, scientists took samples of land, wastewater and air within the SPZ and beyond. Then according to the results of research, the norms were compared. Cartographic data were also used to substantiate the concept of the sanitary protection zone and the observation zone of the Khmelnytsky NPP [Dets, Dmytriv, 2011]. The paper [Ragaisis, Poskas, 2011], considers the approach and methods used to assess the radiological effects on the population that could potentially occur under normal conditions of operation and accident, as well as to demonstrate compliance with current standards. In the article [Bissarinova, Mamyrova, 2016] the methodology of geoinformation approach to mapping of air pollution of the air basin of Almaty is developed. The proposed method of presenting pollution data in the form of an algorithm allows us to build a map of pollution of the surface layer of the atmosphere closest to the actual observed data. The main functionality of GIS-monitoring of the ecological state of the simulation model of the metropolis is to model the spread of pollution for any period for a given geographical area (SPZ, residential area, group of settlement points, etc.).

The given Ukrainian researches are based on normative documents [On approval of the State..., 1996 (SSR 173-96); State Building... SBS B.2.2-12, 2018] in which SPZ of the enterprises is established. The size of the SPZ is calculated individually for each enterprise. The size of the zone is influenced by such factors as the type of object around which the allocation of such a zone, the intensity of its activities, technology. Enterprises are divided into 5 classes according to their harmfulness, according to which SPZ from 50 meters to 3000 meters are installed (Table 1).

Table 1

**Hazard classes and sizes
of SPZ for enterprises**

No.	Hazard class		Width of the sanitary protection zone, m
1	I	A	3000
		B	1000
2	II		500
3	III		300
4	IV		100
5	V		50

Housing, medical institutions (stationary regime), educational institutions (schools, gymnasiums, lyceums, preschool educational institutions), sports buildings, parks, protection zones of water supply sources are not allowed in the SPZ. In SPZ it is possible to place warehouses, garages, buildings related to the maintenance of enterprises, educational institutions (colleges, vocational schools, universities, institutes) without dormitories, clinics, catering establishments (canteens, cafes, restaurants), shops, parking lots, technical water treatment facilities, water cooling facilities, sewage pumping stations, plant nurseries for landscaping of enterprises (State building standards – SBS B.2.2-12: 2018).

Field and remote sensing methods are used to monitor SPZ on compliance with the law. Remote sensing methods are the most optimal, as they allow to obtain detailed and high-quality information about the location of objects in large areas without large material costs. This is facilitated by the use of GIS technologies – a tool for collecting and analyzing geospatial data. Thus, the combination of remote sensing data and ArcGis software package allowed to create a GIS “Surface Waters”, which implements the analysis of the spatial location of objects that adversely affect the environment [Drobnych et al., 2013]. Studies [Ghodeif et al., 2013] are concerned the creation of channel buffer zones in Egypt using the GIS.

The use of GIS in thematic mapping allows to assess the characteristics of the objects of study - attributes, based on the analysis of descriptive and graphical data. The main task of the attribute is to characterize the object [Svitlichny, Plotnytsky, 2002]. To combine attribute databases with graphical data of enterprise location, we need to create appropriate relationships. Relational database management system is a set of relationships. Each relationship is considered as a table of values; the rows in the table represent the set of related data values. These values are interpreted as fact, describing the essence or instance of the relationship [Arvanitis, et al., 2000].

In most studies, spatial data are obtained by analyzing cartographic data, in some works remote sensing data are used. As production facilities are located within cities where infrastructure is changing rapidly, the problem of monitoring SPZ compliance is the availability of up-to-date data on the area, which cannot be obtained based on outdated maps and plans. To obtain up-to-date and relevant spatial and attributive information, we offer a comprehensive application of

cartographic and remote sensing data for modeling and analysis of the location of sanitary protection zones of enterprises.

Aim

To prevent the harmful effects of industrial enterprises on the environment, sanitary protection zones have been created around enterprises, which must comply with the law. However, with the growing urban impact, such areas are changing. Such changes can be monitored using up-to-date terrain data by modeling with modern GIS technology using remote sensing data. This will provide an opportunity to quickly and accurately obtain spatial characteristics of objects and analyze thematic information. Therefore, the aim of the work is to obtain and analyze spatial thematic data on sanitary protection zones of industrial enterprises using basic geospatial data.

Methods

The territory of cities where industrial enterprises are concentrated, are provided with cartographic data (topographic maps and plans, graphic parts of master plans, cadastral maps). Open Internet sources (geoportals) allow to obtain electronic visual data about urban areas in the form of digital electronic maps and aerial and space survey data. Using these sources for the spatial analysis of sanitary protection zones, the method of modeling spatial data based on cartographic and remote sensing data and the analysis of the constructed model was applied.

The general workflow of research, presented on Fig. 1, consisted of four successive stages.

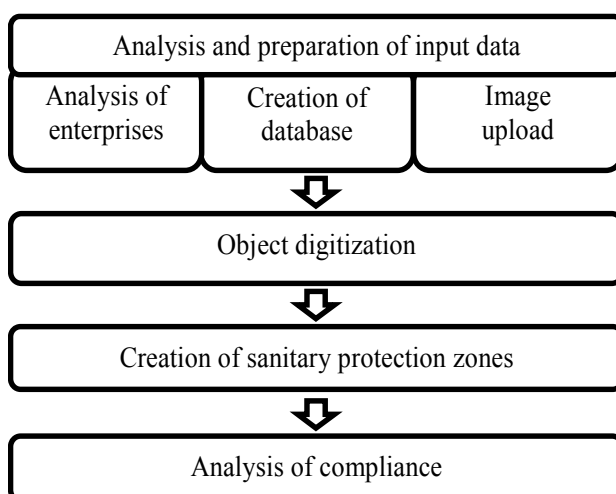


Fig. 1. General workflow of experimental research works

During implementation of the first stage – analysis and preparation of input data - information on 17 production enterprises of Slavuta district, including Khmelnytsky NPP was collected. A database was created and a satellite image of the study area was downloaded.

To analyze the location of enterprises.

For the analysis of enterprises and their boundaries we used basic geospatial data (Article 5 of the Law “On National Infrastructure of Geospatial Data” No. 554-IX from 13.04.2020). The following cartographic data “Zoning plan of the territory of Slavuta, Khmelnytsky region”, “Zoning plan of the territory of Netishyn, Khmelnytsky region”, online service of monitoring the registration data of Ukrainian companies “Opendatabot” and space image of studied area were downloaded into ArcGis environment. During the analysis of the enterprises, their actual location address was checked before displaying the location on the satellite image.

The space image, obtained from the satellite WorldView on August 4, 2018, was downloaded using the program SAS.planet (www.sasgis.org) from the service “Here”. The spatial resolution is 0.5 meters, which satisfies the creation of maps at a scale of 1: 5000 and smaller [Burshtynska, Dolynska, 2011]. Since the width of the SPZ is given with an accuracy of 1 m (SSR 173-96; SBS B.2.2-12: 2018), the resolution of the space image satisfies this accuracy.

Additionally, a map with the locations of roads and buildings for the study area has been uploaded.

The electronic cadastral map was not used due to the following shortcomings:

- the boundaries of land parcels intersect (overlap);
- obtaining data on the land parcels is paid;

During the analysis of enterprises, the actual address of their location was compared with cartographic data and space images.

The obtained images and attribute tables are uploaded to the ArcMap module of ArcGIS. Using space image, studied industrial facilities are refined and digitized along their boundaries (Fig. 2).

The created database contains information about the name of the enterprise, its address, class of sanitary protection zone, registration number, date of registration, code of main activity and its type. Each company is assigned a number. The obtained attribute data of enterprises are entered into the dBase spreadsheet in the ArcCatalog module.



Fig. 2. The boundaries of the enterprise “Slavutsky Brewery” on the administrative map (a) and space image (b)

Using the functionality of ArcMap, the shape file with spatial data “Enterprise Territory” is combined with the attribute tables “Enterprise” and “SPZ” (Fig. 3). The table “SPZ” at this stage of work is filled in accordance with the requirements of the law. Each SPZ class has its own size of territory around the enterprise.

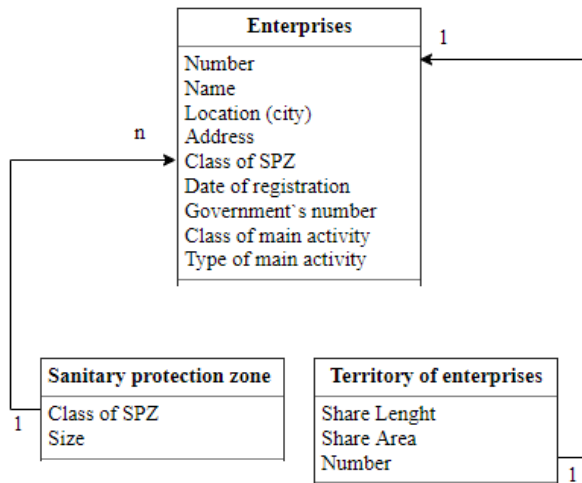


Fig. 3. The scheme of the relationship between the tables “Enterprise”, “SPZ” and the shapefile “Enterprise Territory”

As a result, the corresponding attribute table “Territory of enterprises” with quantitative and qualitative information about production facilities and their boundaries has been received (Fig. 4).

Sanitary protection zones are buffer zones around facilities. To create them, the ArcMap module has a “Buffer” function. The function creates a specific area with a given width from the specified object. Therefore, this function was applied to the “Enterprise Territory” layer. The dialog box indicates the location of the new file, the field from the attribute table “Enterprise Territory” which provides information about the size of the sanitary protection zone of each enterprise.

Shape Length	Shape Area	Назва	Адреса	Дата реєстрації	ЄОПР/ОУ/Номер	Місто
2492	250169	ТОВ "Технозалітінвест"	вул. Київів Саніушко, 95	24.05.2006	34223267	3 м.Славута
1816	103731	ТВД "Славутський РМЗ"	вул.Козацька,122а	27.06.1996	303063	3 м.Славута
1382	87128	ТЗОВ "Юліус ТД"	вул. Привокзальна,1/2	03.06.2011	37846595	5 м.Славута
1876	181082	ТВД "Славутський шкоролюбський завод"	вул. Приміська, 4	12.12.1996	2133509	4 м.Славута
3101	331098	ПАТ "Гевірт керамік продажини"	вул.Козацька,136	07.03.2003	32285199	4 м.Славута
3302	369389	ДП "Славутський комбінат "Будфарфор"	вул.Козацька,122	07.05.2018	42113663	4 м.Славута
1238	73706	ТОВ "Сансервіс"	вул.Острозька,1	20.01.2005	33317231	5 м.Славута
635	14587	ТОВ "Явір"	вул. Привокзальна, 26	18.07.2002	32065063	5 м.Славута
1051	51203	ТОВ "Фабрика по ремонту та виготовленню"	вул. Спаська, 3	27.01.1994	5473453	5 м.Славута
1568	67490	ТОВ "Аква-Родос"	вул. Козацька 122а	09.10.2002	32065083	5 м.Славута
682	24076	ПРАТ "Славутський лівоварний завод"	вул.Мирю, 36	31.01.2008	21334136	5 м.Славута
617	19060	БАТ "Славутський хлібозавод"	вул.Церковна, 29	30.10.1996	300445	5 м.Славута
1552	144289	Філія "Славутський маслоспереробний комбінат"	вул.Богдана Хмельницького	01.05.2004	26548824	5 м.Крутець
4883	456792	ПРАТ "Славутський Солоний завод"	вул.Богдана Хмельницького	15.01.1996	377733	5 м.Крутець
13550	5320360	ВП Хмельницька АЕС ДП "НАЕК "Енергоатом"	вул.Енергетиків 20	09.08.1999	24584681	1 м.Нетішин
1007	62744	ТОВ НВК "Екофарм"	вул.Проміськова 2	27.04.1998	25588983	4 м.Ушацька
1659	114705	ТОВ "Ювента"	вул.Привокзальна 2	05.04.2000	30801338	5 м.Славута

Fig. 4. Attribute table “Territory of enterprises”

The result of the performed actions is a shape file “Sanitary zones”, which contains vector data of sanitary protection zones and information about each enterprise. Fig. 5 shows an example of created SPZ for enterprise, combined with the space image.



Fig. 5. The boundaries of the sanitary protection zones of the enterprises of LLC “Juventa”

The first class of sanitary protection zone has been introduced in the legislation for nuclear power plants. Its width is 3,000 meters around the territory of the nuclear power plant.

Khmelnysky Nuclear Power Plant according to the decision “On approval of land management projects for the organization and establishment of the sanitary protection zone of Khmelnysky Nuclear Power Plant” from 27.03.2013 No. 84/2013 [Order “On Approval...”, 2013] has a sanitary protection zone equal to 2700 m. Therefore, a separate buffer zone was created for it (Fig. 6). This is due to the close location of the city to the nuclear power plant.

Table 2

The ratio of landscaping to the size of the SPZ

SPZ size, m	Area of landscaping (planting trees and shrubs), %
0–300	60
300–1000	50
1000–3000	40

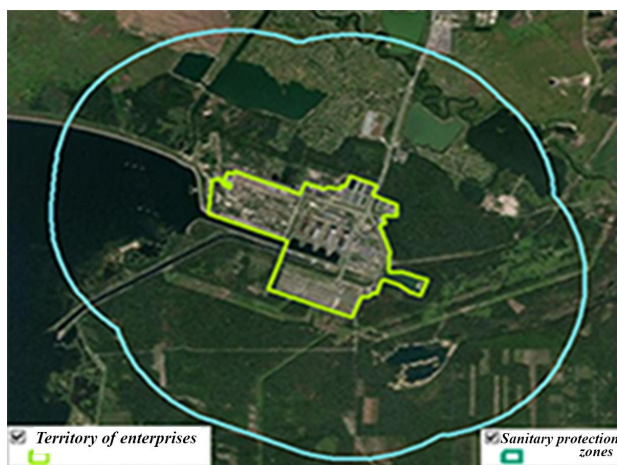


Fig. 6. Buffer zone created for Khmelnytsky nuclear power plant

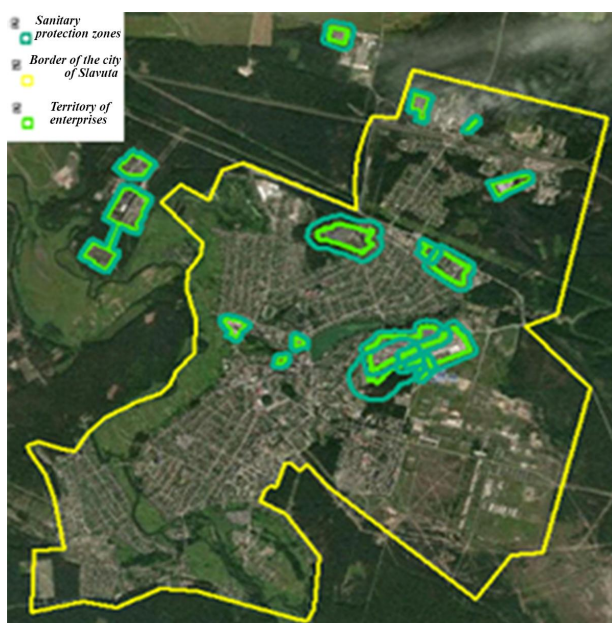


Fig. 7. A fragment of an electronic map with the SPZ

Electronic thematic map has been created for the analysis of sanitary protection zones of the studied enterprises. Fig. 7 shows the part of the created electronic map.

According to the document (SSR 173-96), housing, preschools, inpatient treatment facilities, and water supply sources are not allowed on the territory of the sanitary protection zone. The parcels of SPZ should be landscaped with planting trees and shrubs and well maintained. Table 2 shows the norms of landscaping (planting trees and shrubs) according to the size of the sanitary protection zone.

Therefore, every company is obliged to comply with the rules.

In order to obtain information on landscaping (planting trees and shrubs) of the territory of sanitary protection zones, the data of the territory were digitized. For detailed analysis, not only the vegetation present in the areas of sanitary protection zones is digitized, but also residential buildings (residential buildings with private plots and multi-storey buildings), public buildings (administrative buildings, recreation areas, served for temporary stay of people), storage facilities (garages, warehouses), road network, and water features.

The documentation of urban zoning projects was used for correct classification of the area objects.

After digitization of all objects, the overlay operations were applied to distribute each classified object into its sanitary protection zone.

Overlay operations are operations that superimpose layers on top of each other, creating a new layer.

The result of implementation of overlay operations is the creation of new shapefiles for the five parameters of the sanitary protection zone. The newly created layers include information about the sanitary protection zones as well as about the corresponding objects of classification, namely, their area and perimeter in the sanitary protection zone to which they belong.

Next, we worked with the attribute table of each new shapefile – the new field “Percentage in the SPZ” was created. It includes the ratio of the area of the selected object to the area of the sanitary protection zone, which was calculated used the function “Field Calculator” by the formula (1).

$$X = \frac{Object_area * 100}{SPZ_area} \tag{1}$$

As a result, the obtained data were exported from the ArcMap module, summarized in tabular form and presented in the form of a diagrams.

The analysis shows that the sanitary protection zones of only four enterprises among 16 studied in Slavuta, fully meet the standards. 6 enterprises and the Khmelnytsky Nuclear Power Plant meet the

standards of landscaping. 12 enterprises have violations of SPZ standards. The results are shown on the diagram (Fig. 8), which represent the ratio of area of landscaping and building to the total area of SPZ.

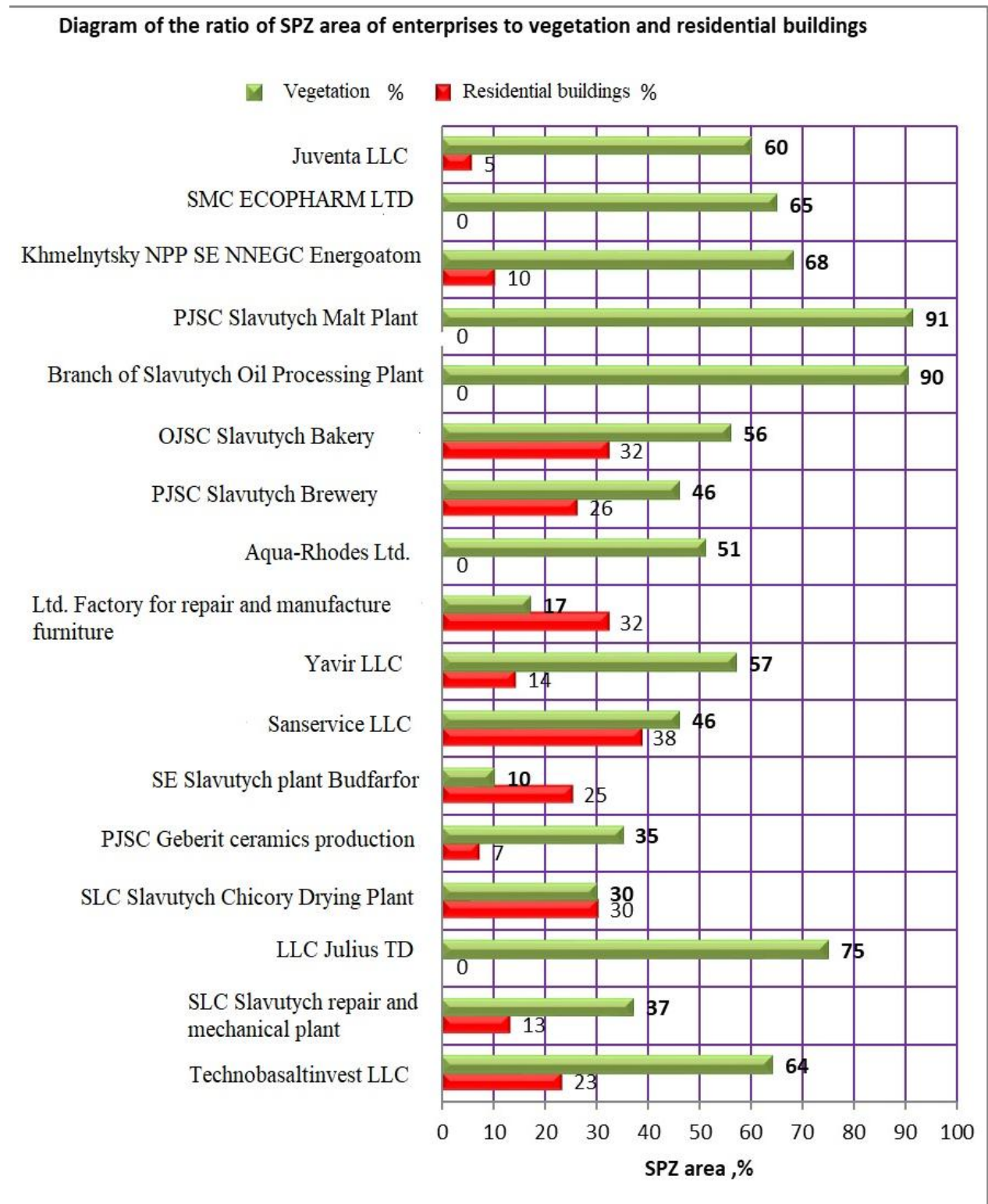


Fig. 8. Diagram with result analysis (green color – vegetation; red color – building)

Results

The electronic thematic map of sanitary protection zones of enterprises has been created and an analysis of these zones with normative standards was carried out.

Scientific novelty and practical relevance

It consists in the complex application of cartographic and remote sensing data for modeling and analysis of the location of sanitary protection zones of enterprises in the city of Slavuta. The obtained thematic geospatial data can serve to eliminate the shortcomings of planning and development of both enterprises and the surrounding infrastructure. The analysis of the results showed an unsatisfactory state of compliance to requirements of sanitary protection zones by industrial enterprises in Slavuta. The tested workflow can be used for modeling and analysis of sanitary protection zones of enterprises that have a harmful effect on the environment, which will increase the level of control in the field of sanitary legislation using GIS technologies.

Conclusions

1. The workflow of the study of the location of sanitary protection zones is formed.
2. Attributive-spatial data of the enterprises of the city of Slavuta and Khmelnytsky nuclear power plant are processed, the database of sanitary protective zones of the enterprises is created.
3. Based on cartographic and remote sensing data the electronic thematic map of the location of enterprises, their sanitary protection zones and the content of these zones were created in the ArcMap module.
4. An analysis of compliance with the requirements for sanitary protection zones of enterprises with the use of overlay operations was implemented. As a result, both shortcomings, violations and compliance with the standards of sanitary protection zones were identified.

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ДОСЛІДЖЕННЯ ПРОСТОРОВОГО РОЗТАШУВАННЯ САНІТАРНО-ЗАХИСНИХ ЗОН ВИРОБНИЧИХ ПІДПРИЄМСТВ МЕТОДАМИ ГЕОІНФОРМАЦІЙНОГО МОДЕЛЮВАННЯ

Актуальною є проблема застосування тематичного картографування територій виробничих об’єктів з метою отримання просторових даних про шкідливий вплив на навколишнє середовище. Одним з факторів, який мінімізує цей вплив, є дотримання санітарно-захисних зон. Території, відведені під санітарно-захисні зони, повинні відповідати актуальним даним про місцевість, змоделювати яку можна сучасними засобами ГІС-технологій з використанням даних дистанційного зондування Землі, що надасть можливість швидко та точно отримувати просторові характеристики об’єктів та проводити аналіз тематичної інформації. Тому, метою роботи є отримання та аналіз просторових тематичних даних про санітарно-захисні зони виробничих підприємств на основі базових геопросторових даних. Методика. Для просторового аналізу санітарно-захисних зон застосовано методику моделювання просторових даних за картографічними матеріалами та даними ДЗЗ і аналіз побудованої моделі. Результати. Створено картографічну модель та проаналізовано

дотримання санітарно-захисних зон виробничими підприємствами м. Славута та Хмельницької атомної електростанції. Наукова новизна. Запропонована технологія дозволила поєднати картографічні дані та дані ДЗЗ у єдине програмне середовище і на їх основі виконати моделювання та аналіз санітарно-захисних зон підприємств міста Славута. Практична значущість. Картографічна модель доповнена актуальними даними ДЗЗ. Аналіз побудованої моделі вказав на сучасний стан дотримання санітарно-захисних зон виробничими підприємствами. Апробовану технологічну схему можна застосувати для моделювання і аналізу санітарно-захисних зон підприємств, які шкідливо впливають на навколишнє середовище.

Ключові слова: тематичне картографування; оновлення карт; дані дистанційного зондування Землі; санітарно-захисна зона; ГІС-технології, ArcGIS.

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