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EVALUATION MODEL OF THE TERRITORIES' STATE IN THE CONTROL AREA OF TECHNO-HAZARDOUS OBJECTS (ON THE EXAMPLE OF KHMELNYTSK NPP)

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The problem

The issue of development of territories has always been, is and will be topical, as land is not only a territorial basis of productive forces and a production basis, but as well a source of life for people. Due to an excessive human-induced load on the environment and an irrational use of land resources, as well as a technogenic impact of big industrial enterprises on the bordering territories the state of environment sharply deteriorates.

In such conditions, it is important to conduct land monitoring, i.e. the complex evaluation of the territories' state by the level of favorability to use lands for their further development, conduct land zoning, and reveal the more or less hazardous parcels for the living and economic use.

At first, it is related to the territories that fall under the impact of constant radiation, as well as the physical and chemical influences, i.e. the control areas of a nuclear power plant (for further NPP).

The analysis of recent research and publications that relate to this problem

The problems of the forecast evaluation of the modern state and the development of territories of different functional determination, monitoring and zoning of lands have been revealed in the works of O.P Dmytriv, P.H. Cherniaha, D.S. Dobriak, A.V. Liusiak, U.S. Khavar, O.U. Melnychuk, O.E. Tkachyk, and L.V. Kornilov.

The researchers have provided the grounds of a stable and ecologically safe development of land use, as well as their rational use; however, the issue of the development of environmental territories of nuclear electrical stations remains open.

Statement of the problem

The aim of research is the creation of evaluation model of the territories' state by the level of favorability of land use within the impact zone of technogenically dangerous objects considering technogenic, social and natural conditions (on the example of the control area of Khmelnytsk NPP) and the possibility of its use. Building such evaluation model will allow to develop some scientifically grounded recommendations on avoiding negative changes of land state, keeping the requirements of ecological safety and the complex development of territories.

The main material

Land resources are a direct economic basis of productive sectors (of industry and agriculture), a displacement system and corresponding engineering technical provision. The concentration and load of industrial objects on the limited territory, demographic tendencies, household methods, and the character of land use specify the conditions of forming and developing the territories of administrative territorial formations.

The control areas of NPP make the territories of different administrative territorial units of the regional and local value of various land categories. That is why it is quite clear that executing the land monitoring and evaluating the territories' state for their further complex development within the control area of NPP practically is related to the difficulties specified by as follows:

1) the insufficient exploration of the complex of human-induced impacts created by unstable social and economic policies;
2) the difficulty of natural climatic conditions of the territories that are being in a constant dynamics;
3) the unknown measure or sample that could be used to evaluate the territories' state by the favorability level of land use.

The main problem here is the fact that it is impossible to mathematically and accurate describe the interrelation of the elements of natural technogenic subsystems [2]. That is why to solve the set objectives the methods of qualimetry should be used.

The accurate forecast of the development of a possible negative impact on the territories within the control area of NPP of a productive process is impossible. With the help of qualimetry evaluation of any parcel of the territory its qualitative indicators in any units (availability to utilization, saturation with infrastructure, attractiveness in the system of similar territories, etc.) could be determined [8].

The qualimetry evaluation model of the territories' state by the favorability level of using lands may be a basis for modelling the development of territories within the control area of NPP, as well as considering all connections among the elements of the system and significance of their impact.

Solving the set objective consists of the following stages:

- revealing main elements of the development object; emphasizing its structural and functional subsystems; and setting interrelations among the object qualities;
- determining the main impact factors on the development of territories and their significance among others basing on the structural analysis of functional subsystems;
- building the scale of evaluation criteria of impact factors on the territory within the control area of NPP;
- zoning of territories by the impact evaluation factors;
- determining the qualimetry evaluation of each factor by impact criteria;
- zoning of territories basing on the qualimetry evaluation of territories by the favorability level of using lands.

The qualimetry evaluation of territories will be performed on the example of 30-km control area of Khmelnytsk NPP.

The surrounding territory of Khmelnytsk NPP falls under the constant influence of radiation due to the industrial activity of electrical power units. It is being sufficiently saturated with high voltage electrical transmission lines (ETLs), the part of which is made of aerial lines 750 κV. It is located in the natural climatic zones of Polissia and the forest-steppe zone, characterized by overdamped landscapes with the high level of organic elements, low level of muddy materials, and the acid reaction of interstitial water (flood drainages, forests, natural and human-induced bow and grassland areas, turf, turf-humus, swamp and other soils). All administrative regions that make the control area of Khmelnytsk NPP by the structure of land fund are considered to be agricultural. In the researches [3, 5], our object of investigation has been explored and described more in details, i.e. 30-km control area of Khmelnytsk NPP.

Basing on the determination of functional subsystems and their structural analysis, the factors have been distinguished having the biggest impact on the development of territories within the control area of NPP [3, 6]. These are the conditions of forming the territories, their radioactive contamination, soil cover, and the establishment of territories. Let us call them the main impact factors. Each factor is described by a set of characteristics that specify its functioning [7].

Some of them are characterized by a positive impact on the territory development, the others – by a negative one.

Radioactive contamination (of soils, surface, and underground waters), as being one of the main impact factors on the territories' development, determines not only the organization of rationally using lands but also the ecological safety of received production and people's health. By this, the main agent of radioactive nuclides' migration in the grown agricultural production is the soil territory coverage [9].

That is why we have decided to scrutinize the factors of radioactive contamination and soil coverage of territories more in details and complement them with the following impact features: density of radioactive contamination, impact of electrical field of electrical transmission lines on the migration of radioactive nuclides in soil, and the types of soil and their mechanical composition.

To determine the importance (significance, priority) of each of these factors among them the term of significance coefficient $\overline{V}$ should be added.

One of main conditions of determining the qualimetry evaluation of factors is the fact that the sum of significances of all indicators should be equal to one. Basing on the fact that all factors in the system influence each other, there exists a direction of relations among them. To determine the advantage relation (the force of leading connection) or equivalence of factors among them the method of approximate flow and expert method of paired comparison has been applied.

In the table 1, the results of determining the significance of main factors on the development of territories of NPP control area have been displayed.

The highest coefficient of significance $\overline{V}$ among the main impact factors on the development of territories within the NPP control area has been received by the radioactive contamination of the territory and the influence of ETL electrical field on the migration of radioactive nuclides. Other factors are equal among them.

Table 1

Results of determining the significance coefficient of main impact factors on the development of territories

Factors of influence	$\overline{V}_j$
Conditions of forming the territories	0,139
Density of radioactive contamination	0,250
Mechanical composition of soil	0,139
Types of soil	0,139
Impact of electrical field of ETL	0,194
Establishment of territories	0,139
$\sum \overline{V}_j$	1,000

The next stage of research is building the evaluation scale of impact criteria of factors on the development of territories within the NPP control area. Each factor will be evaluated by different criteria but by the same evaluation scale.

According to the rules of statistics justification, the optimal number of intervals for a secure processing of data should range from 10 to 20 [1]. For evaluating each factor the interval scale within -3 to +3 with the interval 0,5 should be used. The interval scale gives us a possibility to consider both positive and negative qualities of impact factors with the help of inputting the "conditional" zero point of the scale [1].

The most important impact factor influencing the development of territories within the control area of NPP is its actual radioactive contamination. Currently, the density of contamination of the control area of Khmelnytsk NPP with radioactive nuclides 137Cs is not more than 1 Ci/km2. The dangerous ones are considered to be the spots of Chernobyl origin in the eastern part of location. The evaluation criterion of this factor is the contamination density of territories within the control area of Khmelnytsk NPP 137Cs. The higher the contamination indicator is the lower its evaluation becomes, and, accordingly, the worse the conditions for the development of territories are.

The factor "conditions of forming territories" has in itself both space territorial formations and the social demographic situation and the natural tehnogenic environment, in general. Functioning of the factor should be observed via main kinds of the agricultural activity of people on this territory and via the related with it human-induced loads on the surrounding. Considering all the mentioned above, the level of human-induced load on the territories within the NPP control area should be accepted as a criterion of evaluation of this factor. The bigger the impact of human-induced load is the worse its ecological state becomes, and, accordingly, the conditions for the development of these territories.

By setting the evaluation criteria of the impact level of human-induced load such types of the latter one have

been considered: demographic, industrial, transport, and agricultural [10].

Under demographic load the one should understand the human impact on the surrounding environment as a biological species in the process of its lifecycle. As a main criterion of demographic load the standard indicator of population density should be input.

The industrial load on the territory has been evaluated by the number of launch of contaminating substances from stationary sources, as well as their number per square unit.

The analysis of agricultural load on the territory has been conducted considering the specialization of agriculture. Growing agricultural crops, inputting fertilizers (mineral and organic) and pesticides triggers the contamination of the environment and the goods of farming agriculture. The influence of big animal complexes is equal to the impact on the surrounding with a big city.

The evaluation of transport load has been conducted by the density of motorways and railroads considering their category and move intensity, as well as by the number of emissions of automobile vehicles into the atmosphere.

The soil coverage executes the functions of biological absorber, destroyer and neutralizer of contaminating substances. However, due to the agricultural activity of people, breaking the unity of soil coverage and the high density of contamination, the substances get into plants, in the organisms of animals and people, and then they are accumulated there.

The most widespread on the territory of the control area of Khmelnytsk NPP are grey forest soils and sod-podsolic soils of different levels of podsoling. The latter ones occupy ~20 % of the territory and by their properties may either promote the migration of radioactive nuclides or postpone them and transfer them into vegetation [3]. Mainly it depends on the mechanical composition of soil. By the granulometric composition sandlike and co-sandlike soils prevail; that is a reason for the decrease of soil absorbing property. Their expansion on the whole territory of 30-km control area is significant [3, 5].

In general, by the migrating move 137Cs soils of the NPP impact control area in the system "solution – soil – plant" could be placed in a row: bog soil>sod-podsolic>grey forest>blackearth.

The ecological purity of the grown agricultural production and, accordingly, the dose load on the living population and its health depends on the type and mechanical composition of soil. According to the investigations [9], soils are one of main causes for forming the dose load on the population. Therefore, the soil properties could influence both negatively and positively on the ecological state of territories and their development.

The criterion of evaluation of soil coverage of territories within the control area of Khmelnytsk NPP is based on its qualitative qualities, soil properties related to absorbing, keeping and transfer of radioactive nuclides into plants, we have decided to use the indicator of radioactive nuclides' migration from soils into plants [9]. The worse the properties of soil are the higher the indicator is, and, accordingly, the mark is lower.

The territory of 30-km control area of Khmelnytsk NPP in a sufficient manner is saturated with high-voltage electrical lines, which create huge electromagnetic fields and occupy nearly 1000 ha of lands being mainly agricultural.

The experimental investigations [4] have clarified that the electrical field of ETL of high voltage stimulates the migration of radioactive nuclides deeply into soil and, in such a way, promotes its clearance. It gives a possibility to get the "pure" from radioactive nuclides agricultural products and, accordingly, favors the development of territories.

This factor should be obligatory considered while organizing the territories that fall under the radioactive impact, i.e. the control areas of NPP. The evaluation criterion of this factor will be the availability of ETL of high voltage within the big land use. If ETL passes through the territory, then the mark is "+2", if not then accordingly the mark is "0". The mark "+2" is explained by the fact that the electromagnetic field of ETL has both a positive and negative influence.

The accomplishment of surrounding territories of NPP is, first of all, the availability of human-induced cultivated lands on the territory (forests, agricultural lands, and hydrotechnical buildings), as well as a rational use and protection of lands on the local and economic levels. The term "accomplishment of the territories for land use" means organizing the territories of agricultural firms, enterprises and companies for the optimization of use and protection of agricultural lands; conducting antierodible measures; creating field-protective tree belt areas; and enhancing the structure and location of land territories as well as crop areas.

The experience shows that, in agricultural enterprises, especially in the last economic complicated years, the farmer technologies of housekeeping are violated: the shift of crops is not kept, low norms of organic and mineral fertilizers are applied, and the use of lime-stone for acid soils is not applied at all. Due to a significant break of land massives among the existing agricultural enterprises, farms and common people using land it is really hard to evaluate the state of the territory adjustment.

On a governmental level, no regulation or normative document, which could regulate the order of conducting and evaluating the adjustment of territories having the significant impact on the development of territories, has been enacted. The scholars have studied this issue casually or in some of its directions [10].

We have made a decision to evaluate the impact of adjusting territories within the NPP control area by plowing, foresting and adjusting of territories within the administrative territorial units that are included into 30-km zone of Khmelnytsk NPP, and as well by the saturation of human-induced agrolandscapes (the availability of transport network, contour meliorative organizating of territories, antierosion measures, etc.).

If the territory has a natural forest, is well saturated with human-induced agrolandscapes, has a low plowing and erosion, thus it has the favorable conditions for the development of territories and should have the mark "+2". In an opposite case "-2", thus it means that the territory is not adjusted and does not demand the measures directed at

providing the favorable ecological state and the development of territories to it.

The criteria of main impact factors on the development of territories and their mark are provided in the table 2.

After setting the criteria and determining their mark by each factor, keeping the principle of prevailing and homogeneity on the territory of this or that evaluation criterion, the zoning of the territory of the control area of Khmelnytsk NPP with using the program complex ArcGIS has been conducted.

The qualimetry evaluation of the territories' state by the favorability level of using lands of the set regions has been determined by the following formula:

$$O_{ij} = \overline{V_j} * O_{kj},$$

where O_{ij} – the qualimetry evaluation of *i* region of *j* factor;

$\overline{V}_j$ – the coefficient of weight of *j* factor;

O_{kj} – the mark of *k* criterion of *j* factor.

On the last stage of research, while using the program product ArcGIS with the method of algebraic sum of total score from the set regions (by each impact factor), the evaluation model of complex development of territories within the control area of Khmelnytsk NPP has been built (fig. 1). As a result, the characteristic zones with different evaluation of the territories' state by the favorability level of land usage have been underlined. Basing on the conducted zoning the most favorable and critically hazardous territories for leading agricultural production and the life of population, as well as for the complex development of these territories have been determined:

-2,00…-1,50 – critically hazardous territory;

-1,49…-1,00 – very unfavorable territory;

-0,99…-0,50 – unfavorable territory;

-0,49…0,00 – slightly unfavorable territory;

0,01…0,50 – relatively favorable territory;

>0,51 – favorable territory.

By this, the evaluation of the territories' state of populated areas has not been determined.

The evaluation scale has been developed considering the fact that the impact factors on the development of territories within the NPP control area have both a positive and negative impact on it. Therefore, the optimization criterion of the qualimetry evaluation model of the territories' state by the favorability level of land use for their complex development within the NPP control area is the highest evaluation value of *j* factor in *i* zone, i.e. the function of type

$$\sum_i O_{ij} \to \max.$$

The quantative and spacial analysis of the evaluation model of the territories' state for their complex development has indicated that the biggest percentage of the territories within the control area of Khmelnytsk NPP, particularly 34,0 %, is occupied by the lands with the evaluation level "slighly unfavorable territory".

The results of quantative and spacial analysis of the evaluation model of the territories' state within the control area of Khmelnytsk NPP have been provided in the table 3.

The territory with the total score "from -2,00 to -1,00" is characterized by the high intensity of industrial production, human-induced load, the significant levels of radioactive contamination (5-15 Ci/km2), and the inclusion of heavy metals in soils being higher in dozens of times than MRL. The territory is not suitable for the use in agricultural production and its further complex development.

The territory with the total score within "from -0,99 to -0,50" is characterized by a significant number of industrial enterprises, the average density of engineering transport infrastructure, the level of radioactive contamination from 1 to 5 Ci/km2, and the inclusion of heavy metals in soils on the level of MRL. It demands the complex of special organizational, agrotechnical, agrochemical, and technological measures of re-division of lands by their purposeful determination, which are aimed at decreasing radioactive contamination and technogenic impact, in general.

The territories with the total score "from -0,49 to 0,50", thus being less - and relatively favorable, are characterized by a little number of industrial firms, low density of engineering transport infrastructure, the level of radioactive contamination from 0,1 to 1,0 Ci/km2, and the inclusion of heavy metals in soils on the level or a slight excess of percentage abundance. It is recommended to conduct the organizational, agrotechnical, agrochemical, and technological measures to adjust the radioactively contaminated lands and the measures aimed at land protection, renewal of land productivity, and the rational use of territories.

The territory with the total evaluation state of territories for their complex development more than 0,51 does not fall under any industrial and human-induced load. This territory does not foresee any special means to be taken concerning land use.

According to the spacial analysis, the critically hazardous territories prevail within 15-km zone towards the location of Khmelnytsk NPP and as well in the sourthern part of the control area. These ones are mainly the territories of Slavuta, Iziasliv, Shepetivka and Bilohiriaia districts. The territories of these districts are characterized by the availability of radioactive spots of Chornobyl origin, the big plowing and erosion of the territory, and the significant human-induced load.

A slighly better situation has formed in the nothern part of the control area (Rivne region), where the slightly and relatively favorable territories for their complex development, conducting the agricultural production and the life of the population prevail. The most favorable territory, which is characterized by a high level of evaluating the territories' state for its development, is the north eastern part of 30-km zone of Khmelnytsk NPP. It has the biggest square of expansion, in total 2 826,0 ha, i.e. 1,0 % of the whole territory.

Table 2

Qualimetry evaluation of the territories' state by the main impact factors

Factors of influence	Coefficient of weight, $\overline{V}_j$	Evaluation criterion factors of influence	Evaluation, O_{kj}	Total score, O_{ij}
1. Conditions of forming the territories	0,250	0 – 3	0	0
		3 – 5	-0,5	-0,12
		5 – 9	-1,0	-0,25
		9 – 11	-1,5	-0,37
		11 – 13	-2,0	-0,50
		13 – 15	-2,5	-0,62
		>15	-3,0	-0,75
2. Density of radioactive contamination	0,139	Slight	-0,5	-0,07
		Weak	-1,0	-0,14
		Average	-1,5	-0,21
		Considerable	-2,0	-0,28
		Critical	-2,5	-0,35
		Critical local	-3,0	-0,42
3. Types of soil	0,139	Sod-podzol	-3,0	-0,42
		Fenny	-3,0	-0,42
		Sod	-1,0	-0,14
		Meadowy	-0,5	-0,07
		Chernozems	0,5	0,07
		Grey	0,5	0,07
4. Mechanical composition of soil	0,139	Gritty	-3,0	-0,42
		Clay sandy	-1,5	-0,21
		Sandy loam	-0,5	-0,07
		Easy-clay	-0,5	-0,07
5. Impact of electrical field of ETL	0,194	Passes through the territory	2,0	0,39
		Do not passes	0,0	0,0
6. Establishment of territories	0,139	Orderly	2,0	0,28
		Not ordered	-2,0	-0,28

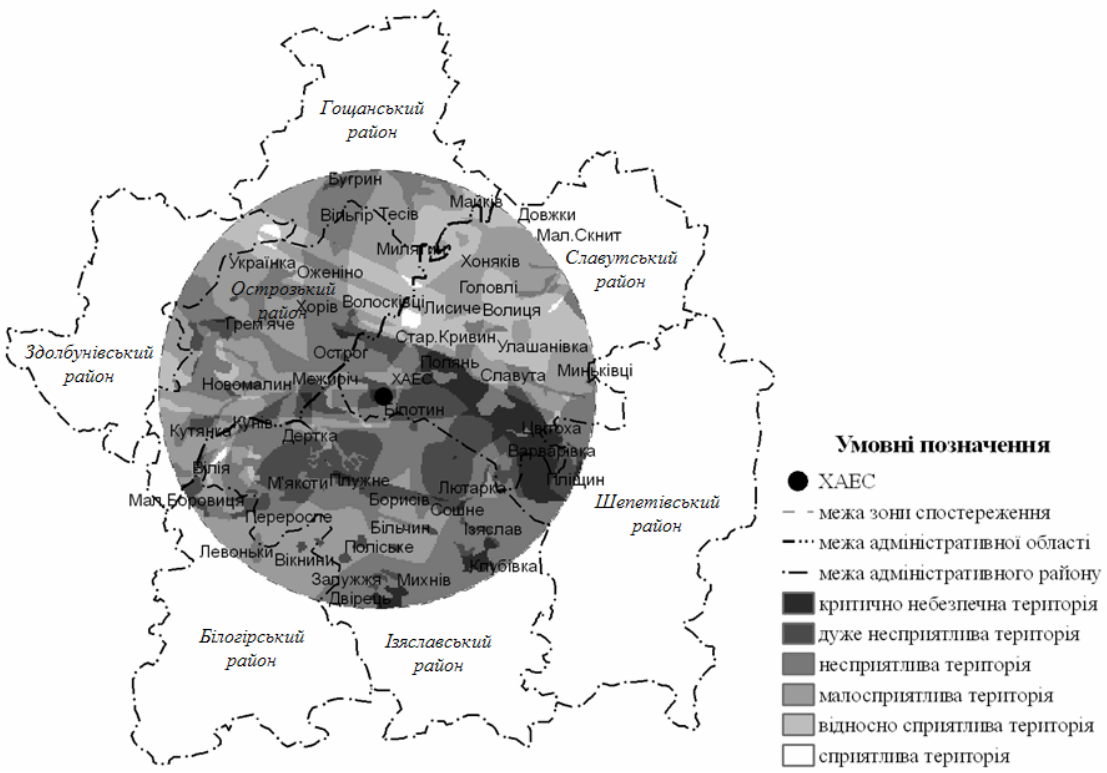

Fig. 1. Model of the complex evaluation of the territories' state by the favorability level of used lands within the control area of Khmelnytsk NPP

Table 3

Evaluation of the territories' state for their complex development within the control area of Khmelnytsk NPP

Evaluation of the territories state	The favorability level of land usage	The area	
		%	ha
-2,00…-1,00	Critically hazardous	5,0	14130,0
	Very unfavorable territory	14,0	39564,0
-0,99…-0,50	Unfavorable territory	32,0	90432,0
-0,49…0,50	Slightly unfavorable territory	34,0	96084,0
	Relatively favorable territory	14,0	39564,0
>0,51	Favorable territory	1,0	2826,0
Total		100	282600,0

Conclusions

The evaluation model of the territories' state by the favorability level of land use will simplify the further planning of the measures aimed at increasing the development of territories, determining the priority of their conduct, and will allow to shape the new principles of organizing the territories of land use, as well as give some recommendations concerning their stable development and rational use.

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Evaluation model of the territories' state in the control area of techno-hazardous objects (on the example of Khmelnytsk NPP)

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The evaluation model of the territories' state by the favorability level of land use within the impact zone of technogenically hazardous objects (on the example of the control area of Khmelnytsk NPP) has been created.