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Assessment criteria for ecological and geological zoning of territories

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Abstract
Aim. Development of new approaches to ecological and geological zoning of territories based on an integrated assessment of the state of abiotic and biotic components of the environment.
Material and Methods. The methodology of teratological analysis of leaf blades is presented, which makes it possible to determine the morphological deformation of vegetational elements associated with external negative influences.
Results. The degree of comfort of the environment, as determined by a set of quantitative indicators, is emphasised. The process of generalization of the entire body of information is embodied through the creation of a map of ecological-geological zoning by combining and "scanning" individual thematic maps using overlays. The legend, as the basis for the logical classification of the map of ecological and geological zoning, fixes its object, subject and defines the semantics.
Conclusion. Practical recommendations for the construction of maps of ecological-geological zoning within the framework of the proposed methodology are presented through the example of large enterprises engaged in petroleum product logistics.

Key Words
Criteria, assessments, ecological-geological, ecological-geological map, integral approach, zoning, comfort, vital activity.

Критерии оценок при эколого-геологическом районировании территорий

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Резюме
Цель. Разработка новых подходов эколого-геологического районирования территорий, основанного на интегральной оценке состояния абиотических и биотических компонентов окружающей среды.
Материал и методы. Использована методология тератологического анализа листовых пластин, позволяющего определять морфологическую деформацию элементов растительности, связанную с внешними негативными воздействиями.
Результаты. Выделены степени комфортности среды жизнедеятельности, определяемые набором количественных показателей среды. Процесс обобщения всего объема информации воплощается в виде создания карты эколого-геологического районирования путем совмещения и «просвечивания» отдельных тематических карт с применением способа оверлейных операций. Легенда, как логическая классификационная основа карты эколого-геологического районирования, фиксирует ее объект, предмет и определяет семантику.
Заключение. Представлены практические рекомендации по построению карт эколого-геологического районирования в рамках предлагаемой методики на примере крупных предприятий логистики нефтепродуктов.

Ключевые слова
Критерии, оценки, эколого-геологические, эколого-геологическая карта, интегральный подход, районирование, комфортность, жизнедеятельность.

INTRODUCTION

The undertaking of engineering environmental surveys aims to form a basic block of information about the state of environmental components and possible sources of pollution in the areas of a planned development [1]. One of the main objectives is the assessment of the environmental conditions of the territory surveyed. The requirements for the compilation of environmental maps (schema) of the current and forecasted state of a given research area are indicated, as are appropriate scales depending on the stage of the engineering environmental surveys. In this regard the name of these documents is debatable. Ecological mapping involves emphasizing the state of an environment's biotic components. Generally, ecological maps demonstrate features of the interaction of living organisms with their environment. An ecological map is a special purpose map that displays an image of the territorial locations of environmental factors [2]. Ecological maps of the spatial distribution of individual ecosystems, maps of biotopes, populations, etc. were compiled according to existing methodologies. The term "engineering ecological map" was given in SNiP 11-02-96 "Engineering surveys for construction. Basic provisions." Within the framework of this definition, an engineering ecological map is supposed to represent graphically the current ecological state of the environment and/or a forecast of its change for a given time interval [3].

In engineering and environmental surveys, the abiotic components of the environment, such as the atmosphere, soils, soils of the aeration zone, surface, groundwater, exogenous geological and geotechnical processes and geological fields serve as the main objects of investigation. These are assessed using sanitary and health indicators that provide normative standards for the influence of external factors on the health status of the population. Among such indicators are maximum permissible concentration (MPC), maximum permissible level (MPL) and approximate permissible concentration (APC). It should be stressed that the assessment of the impact on human health occurs precisely through the designated system of ecological and geochemical indicators. However, to focusing solely on humans, while excluding other ecosystems, is an erroneous approach. This approach is called anthropocentric, in isolating a human from the system of general biota does not allow us to solve the main problem – of providing a comfortable living environment as a whole. This circumstance was repeatedly emphasized in the works of V.T. Trofimov *et al.* [4]. Indicators of the comfort of life are of great importance, as they determine zones optimal for human beings.

MATERIAL AND METHODS OF RESEARCH

We consider that it is appropriate to use the term "environmental geological map" in the process of executing engineering environmental surveys. According to V.T. Trofimov and D.G. Zieling, an ecological and geological map is "a graphical and mathematical model of an ecological and geological situation, that gives, on a topographical basis, a generalized image of the assessment of the state of the components of the lithosphere, reflecting its ecological functions" [5]. In particular, ecological and geological maps are a category of integrated maps that display the levels of transformation of the ecological functions of the lithosphere under the influence of anthropogenic load, as diagnosed by the state of environmental comfort. The objects of ecological and geological mapping are complex formations, including soils, the surface part of the lithosphere, surface and underground waters, elements of the technosphere, biosphere, their properties and observation systems. At the same time, a set of assessment maps is compiled for the abiotic and biotic elements of the environment under investigation. The assessment criteria for the parameters have been developed by a number of modern regulatory documents, based on a comparison of the results with the relevant maximum permissible parameters. Thus, the conversion features of geophysical fields, as well as the physical parameters of the environment, are displayed in the form of an estimated ecological and geophysical map based on a comparison of obtained data obtained with indicators of maximum permissible levels. The assessment of lithosphere elements is carried out in order to identify the geomorphological, lithological and geodynamic factors that affect biota elements. Analysis of fault activity is necessary from the point of view of the formation of pathogenic ecological-geophysical and ecological-geochemical anomalies. The fact that a given territory is affected by exogenous processes has a significant effect on the comfort of biota habitat and the stability of engineering structures. Soils constitute a unique upper layer of the lithosphere, formed as a result of geological, climatic and biological influences. They are the main functional component of biota reproduction, the base of the ecological pyramid. Ecological-geochemical and ecological-biotic soil assessment are presented through a series of thematic maps. The ecological state of surface and ground waters is assessed by comparing the parameters of their state with maximum permissible values. As a result, the total pollution indicators in relation to MPC are calculated. In assessing the state of surface waters, mapping of the processes of flooding of adjacent territories is important. The migration features of polluting elements into groundwater are determined by the level of their natural security and reflected in the corresponding maps. Evaluation of the state of ecosystems during engineering and environmental surveys is appropriate for vegetation as a basic element of the ecological pyramid. In this case, biological methods that do not require special biological preparation can be used. Among the methods mentioned are:

- biological diversity method;
- projective cover method;
- mowing method;
- teratological method.

The biotic criteria for ecological and geological assessments are presented in the works of B.V. Vinogradov (Table 1). For most of the selected criteria, quantitative indicators are proposed that can be used in ecological and geological zoning.

Recent studies have shown that plants can be used as test objects for engineering environmental surveys. According to their various characteristics, the state of the environment and changes over a number of years can be assessed. To assess the state of the environment, it is possible to use physiological, biochemical, genetic, cytological (at the cell level), as well as morphological characteristics. By identifying changes in morphological parameters in plant objects, it is possible to assess environmental comfort levels and to predict the danger to biota and humans in particular.

Table 1. Botanical indicators of ecosystem disturbance (according to B.V. Vinogradov) [6]
Таблица 1. Ботанические показатели нарушенности экосистем (по Б.В. Виноградову) [6]

Indicators Показатели	**Ecological normal area** Зона экологической нормы	**Ecological risk area** Зона экологического риска	**Ecological crisis area** Зона экологического кризиса	**Ecological disaster area** Зона экологического бедствия
Deterioration of the species composition of natural vegetation Ухудшение видового состава естественной растительности	Natural change of dominants, subdominants and main species Естественная смена доминантов, субдоминантов и характерных видов	Decrease in the abundance of dominant, especially beneficial species Уменьшение обилия господствующих, в особенности полезных видов	Change of dominant species and secondary, mainly, not eaten weeds and poisonous Смена господствующих видов, а вторичные, в основном, непоедаемые сорные и ядовитые	Decrease in the abundance of secondary species, there are practically no useful plants Уменьшение обилия вторичных видов, полезных растений практически нет
Change of habitats Изменение ареалов	Absence Отсутствие	Weakening, thinning Ослабление, изреживание	Separation, reduction Разделение, сокращение	Extinction Исчезновение
Vegetation damage Повреждение растительности	Absence Отсутствие	Damage to the most sensitive species – conifers, lichens Повреждение наиболее чувствительных видов – хвойных деревьев, лишайников	Damage to medium sensitive species Повреждение среднечувствительных видов	Damage to insensitive species of herbs, bushes Повреждение слабочувствитель-ных видов трав, кустарников
The appearance of teratological deviations Появление тератологических отклонений	Absence Отсутствие	Sparse Редкое	Sporadic Спорадическое	Mass Массовое
Simpson's Diversity Index Decrease, % Уменьшение индекса разнообразия Симпсона, %	Less than 10 Менее 10	10-20	25-50	More than 50 Более 50
Amount of forests, zonal, % Лесистость, % от зональной	More than 80 Более 80	60-70	50-30	Less than 10 Менее 10
Stands damage, % Повреждение древостоев, %	Less than 5 Менее 5	10-30	30-50	More than 50 Более 50
Damage to needles, % biomass Повреждение хвои, % биомассы	Less than 5 Менее 5	10-30	30-50	More than 50 Более 50
Death of crops, area % Гибель посевов, % площади	Less than 5 Менее 5	5-15	15-30	More than 30 Более 30
Projective cover of pasture steppe and semidesert vegetation, % of normal Проективное покрытие пастбищной степной и полупустынной растительности, % от нормы	More than 80 Более 80	60-70	50-30	Less than 10 Менее 10

The Department of Ecological Geology of Voronezh State University has developed a methodology for the teratological analysis of vegetation blades. This analysis allows us to determine the morphological deformation of the elements of bio systems associated with external negative influences. Thus V.M. Zakharov *et al* chose weeping birch leaves as an object of study and conducted investigations leading to the identification of correlation dependences between atmospheric pollution and deformation of birch leaf veins.

In the framework of engineering environmental surveys, we propose the use of teratological methods based on the study of the asymmetry coefficient of a leaf of herbaceous vegetation. Under natural conditions, where environmental indicators are favourable to vegetation, the leaf surface has a shape symmetrical about the axis.

The coefficients of symmetry (Ks) were experimentally identified and calculated by statistical processing of a significant amount of leaf blades of herb vegetation.

$Ks=S_1/S_2*100\%$,

where S_1 – major area of the leaf blade, mm^2;

S_2 – minor area of the leaf blade, mm^2.

Experimentally, we have developed the following criteria for the ecological state of the environment in terms of teratological indicators:

1. 95-100% – ecological norm;
2. 81-94 – ecological risk;
3. 71-80 – ecological crisis;
4. less than 70 – ecological disaster.

Criteria for ecological and geological assessments and environmental levels were developed by Yu.E. Saetom, V.T. Trofimov, D.G. Zeeling, I.I. Kosinova *et al*. [4; 7; 8] (Table 2). It is proposed to correlate the assessment of the degree of comfort of the living environment with ecological and geochemical indicators. Accordingly, the levels of environmental assessments are linked to the degree of comfort of the living environment.

The process of summarizing the entire amount of information is implemented through the creation of a map of ecological and geological zoning by combining and "trans-illuminating" all constructed maps via overlays. It should be emphasized that a map of ecological-geological zoning carries integral information on the complex of ecological-geological criteria. The map is constructed in a semaphore version: a state of ecological disaster being recorded in brown, a state of ecological crisis in red, ecological risk in yellow and the environmental norm in green. The dividing role of colour graphics on the map is obvious. A colour tone variable gives quantitative information, arranges it according to the tones of a single colour and combines the action according to the different colour tones. Assessment of the state of the considered ecosystems is based on health parameters and quantitative indicators of the state of biota. In this regard, the presence of at least one factor of abiotic or biotic origin, characterized by crisis values or environmental disaster values, determines the territory as a whole according to the category of corresponding grades of assessment.

Thus, in the process of constructing a map, areas of ecological disaster, crisis and risk are first identified. Sites assigned to the ecological norm are characterised by the values of factors that are as close to natural as possible, optimal, ensuring a balance between living and non-living nature. In its final form, zoning is determined by the leading factor: first, by the presence of factual spaces with the maximum level of negative impact (disaster and crisis areas); second, with a minimum level (ecological norm areas) and, third intermediate – pre- and hypocomfortable areas. Within the selected areas, the number of leading factors is shown in tone shades. The darkest tone determines the total impact on the territory of three or more leading factors that determine the state of the ecological and geological situation (EGS). The intermediate is characterized by the combined effect of two leading factors, the lightest indicates the territory where the assessment of the state of EGS is determined by one leading factor.

Such a division allows us to obtain a differentiated assessment of the state of ecological and geological systems, as the basis for the most efficient development of territories.

The digital language of ecological and geographic mapping (EGM) involves the use of digital and alphabetic images. Roman numerals indicate the zone of comfort of the environment (I – extreme, II – uncomfortable, III – hypo and pre-comfortable, IV – comfortable), while Greek numerals indicate the presence of related factors. Leading factors determine the assessment of the state of the EGS, and related factors are additional information. Literal values that determine the qualitative characteristics of the evaluation criteria are placed after the digital symbols. Accordingly "II SN 3ET" should be interpreted as follows: the territory is assessed as being in a state of discomfort. The leading criteria for the formation of the assessment in this case are maximum soil pollution (S) and noise levels (N). Additionally, (3) EGS experiences the harmful effects of erosion processes (E), the teratological transformation of vegetation (T) is recorded at the level of pre-comfortable state of the environment; other components of the environment are normal, not being affected by the conversion processes. The numerical values of the parameters corresponding to the selected taxonomic units are given in symbols.

Testing of the proposed methodology is presented through the example of a map of ecological and geological zoning of an area where a first-level petroleum storage depot is located in Voronezh. This petroleum storage depot has been operating since 1947 and is used for receiving, storing and periodically replacing fuel for TS jet engines, as well as for the storing of A-76 petrol.

The basis for constructing a map of ecological and geological zoning is a radial sampling schema at 10, 25, 50, 100, 250, 500, 1000, 1500 m distances from the petroleum storage depot at its centre.

In the area investigated, soil and near-surface sediment samples taken from a depth of 0.2 m from the earth's surface were studied. Samples for analysis were formed by "envelope" method of taking five samples from a square site in such a way that each sample is part of the soil or near-surface deposits typical of this area. The mass of each sample was at least 1 kg. Samples were analysed for oil content.

Teratological analysis of vegetation was carried out using the same sampling method as the soil. At each point, at least 5 plantain or dandelion leaves were selected. In our case, the dandelion was the indicator. Using this indicator, the symmetry index was calculated. The choice of vegetation type was related to the analysis of the long-term accumulation of pollutants in dandelion elements.

Table 2. Habitat comfort degree assessment
Таблица 2. Оценка степени комфортности среды жизнедеятельности

	Pollution levels Уровни загрязнения	**Valid** Допустимое	**Moderately dangerous** Умеренно опасное	**Dangerous** Опасное	**Highly dangerous** Высоко опасное	**Extremely dangerous** Чрезвычайно опасное
	Ecosystem Assessment Оценка состояния экосистем	**Norm** Норма	**Ecological risk** Экологический риск		**Ecological crisis** Экологический кризис	**Ecological disaster** Экологическое бедствие
	Habitat comfort degree assessment Оценка степени комфортности среды жизнедеятельности	**Comfortable** Комфортное	**Precomfortable** Прекомфортная	**Hypocomfortable** Гипокомфортная	**Uncomfortable** Дискомфортная	**Extreme** Экстремальная
Soils Почвы	**Toxic elements (SPC)*** Токсические элементы (СПК)	<8	8-16	16-32	32-128	>128
	Organic compounds (MPC) Органические соединения (ПДК)	<1	1-2	2-5	5-10	>10
Bottom sediment Донные отложения	**Toxic elements (SPC)*** Токсические элементы (СПК)	<8	8-16	16-32	32-128	>128
	Organic compounds (MPC) Органические соединения (ПДК)	<1	1-2	2-5	5-10	>10
Underground hydrosphere Подземная гидросфера	**Hydrodynamic situation (level change %)** Гидродинамическая обстановка (% изменения уровня)	<20	20-60	60-100	>100	>100
	Hydrochemical characteristic Гидрохимическая характеристика; **Impurity elements** Загрязняющие элементы; **1 Hazard Class** 1 кл. опасности	<1	1-1.5	15-2	2-3	>3
	2 Hazard Class 2 кл. опасности	<1	1-2	2-5	5-10	>10
	3-4 Hazard Class 3-4 кл. опасности	<1	1-5	5-10	10-15	>15
Surface water Поверхностные воды	**Toxic chemical elements, macroelements, organic elements (MPC)** Токсические химические элементы, макроэлементы, органические элементы (ПДК); **1-2 Hazard Class** 1-2 кл. опасности	<1	1-2.5	2.5-5	5-10	>10
	3-4 Hazard Class 3-4 кл. опасности	<1	1-25	25-50	50-100	>100
Snow Снеговые выпадения	**Impurity elements (background)** Загрязняющие элементы (фон); **1 Hazard Class** 1 кл. опасности	<1	1-1.5	1.5-3	3-5	>5
	2 Hazard Class 2 кл. опасности	<1	1-2	2-5	5-7.5	>7.5
	3 Hazard Class 3 кл. опасности	<1	1-3	3-7.5	7.5-12.5	>12.5
Vegetation Растительность	**Impurity elements (background)** Загрязняющие элементы (фон); **1+2 Hazard Class** 1+2 кл. опасности	<1	1-2	2-5	5-10	>10
Herbaceous Vegetation Травянистая растительность	**Teratological indicators** Тератологические показатели; **Ks, %** К симметрии,%	85-100	81-94		71-80	Less than 70 Менее 70

*– SPK=СПК

The ecological and hydrogeochemical schematic map produced is based on observations made through a network of 13 wells located on the petroleum storage depot territory along with drainage platforms, as well as of 5 wells located on the territory close to the enterprise.

RESULTS AND DISCUSSIONS

Ecological and hydrogeochemical testing of wells was carried out in March, June and October 2019 in order to identify the dynamics of pollution by petroleum products. Samples were taken from the underground waters of the Neogene-Quaternary aquifer in conditionally clean wells, where petroleum products were not fixed, and in wells which are contaminated with oil products.

Based on the results of these investigations, assessment maps of abiotic and biotic indicators of the environment state were constructed.

The ecological and geochemical map of the assessment of the state of soils and near-surface sediments (Fig. 1) shows the formation of a contour elongated in the northwest direction, which includes the territories of the petroleum storage depot of the first (central part) and second (south-eastern part) levels. In the northern part of the studied area, ecological crisis levels for soils develop as a result of transportation on unpaved roads.

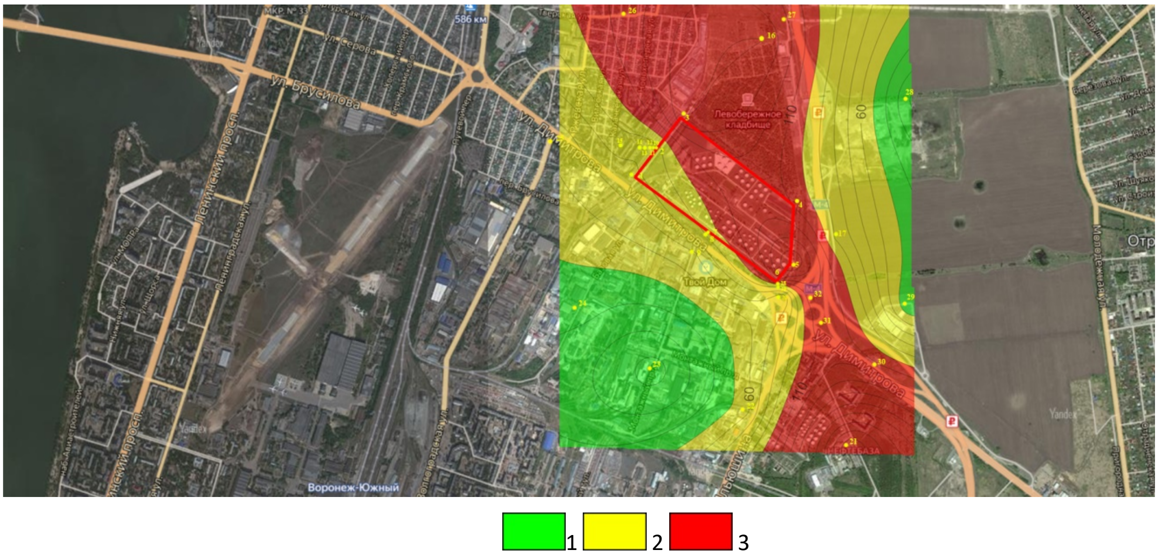

Figure 1. Ecological-geochemical assessment map of near-surface sediments.
1 – content of petroleum products less than 1000 mg/kg;
2 – content of petroleum products 1000-5000 mg/kg;
3 – content of petroleum products is more than 5000 mg/kg
Рисунок 1. Карта-схема эколого-геохимической оценки приповерхностных отложений.
1 – содержание нефтепродуктов меньше 1000 мг/кг;
2 – содержание нефтепродуктов 1000-5000 мг/кг;
3 – содержание нефтепродуктов больше 5000 мг/кг

Vegetation is an indicator of the state of near-surface sediments, as indicated by the similar structure of the uncomfortable area. Its area is slightly smaller than the previous one but corresponds to the level of habitat (Fig. 2). If the area of uncontaminated soil and near-surface sediments in the study area is about 20%, then these areas account for 12-15% of vegetation pollution.

Ecological and hydrogeochemical state assessment of the Neogene-Quaternary aquifer within the petroleum storage depot revealed levels of petroleum product pollution corresponding to extremal and uncomfortable assessments (Fig. 3). Levels in excess of the relevant MPCs vary from 3.3 to 22.7 times. The development of the crisis situation is stopped by ongoing barrage work, which is carried out on average 5-8 times a month, excepting the winter period.

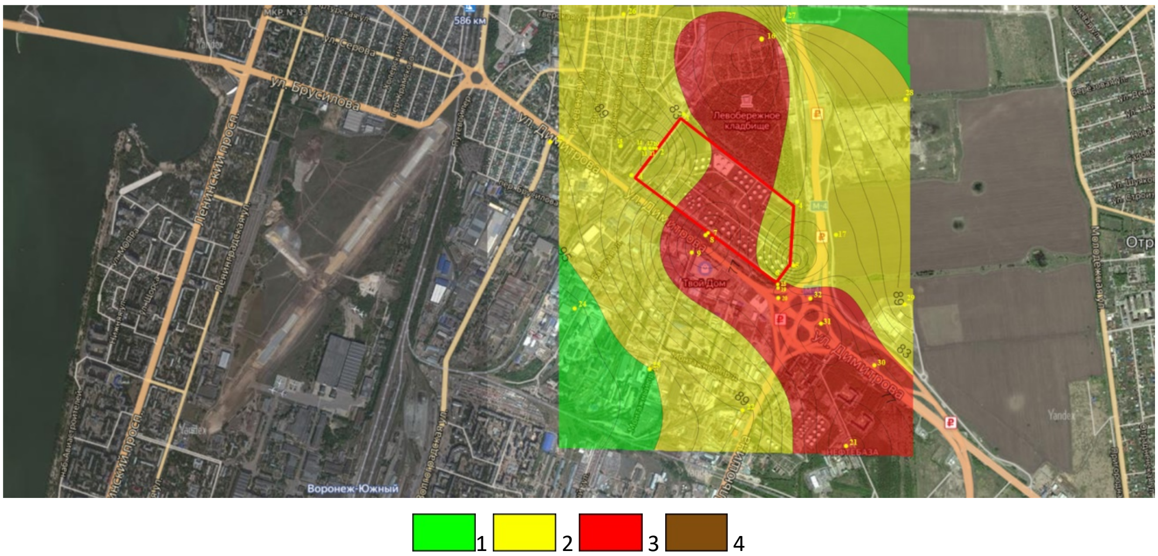

Figure 2. Ecological assessment map of vegetation (teratological change indicator).
1 – ecological norm; 2 – ecological risk; 3 – ecological crisis
Рисунок 2. Карта-схема экологической оценки состояния растительности (показатель тератологических изменений).
1 – экологическая норма; 2 – экологический риск; 3 – экологический кризис

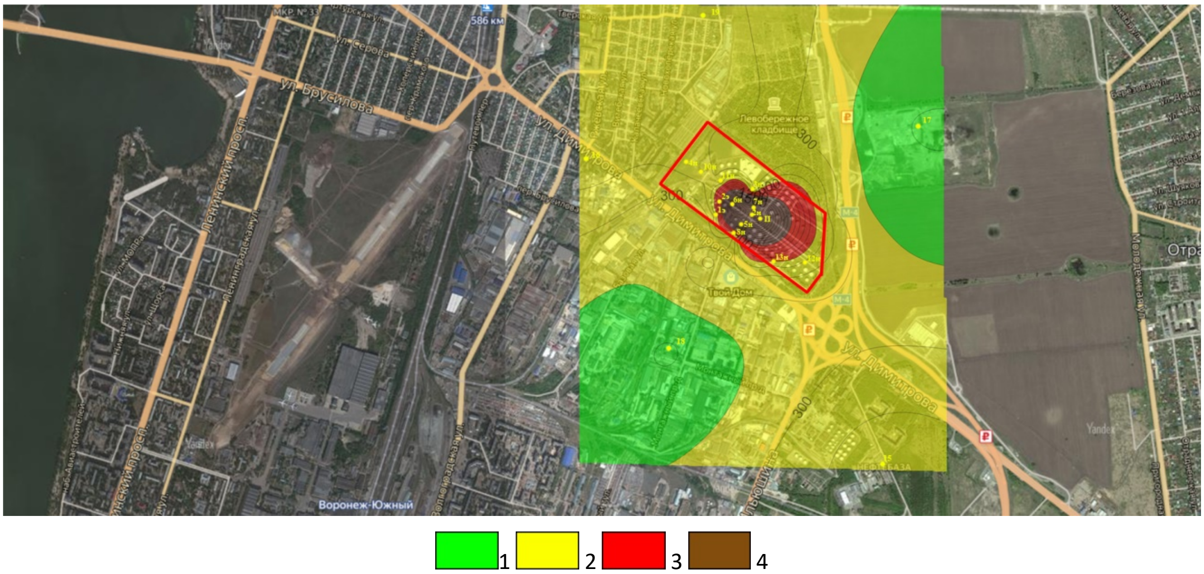

Figure 3. Ecological-hydrogeochemical assessment map of the state of the Neogene-Quaternary aquifer complex. Petroleum products content: 1 – less than 1 MPC; 2 – 2-5 MPC; 3 – 5-10 MPC; 4 – more than 10 MPC
Рисунок 3. Карта-схема эколого-гидрогеохимической оценки состояния неоген-четвертичного водоносного комплекса. Содержание нефтепродуктов: 1 –менее 1 ПДК; 2 – 2-5 ПДК; 3 – 5-10 ПДК; 4 – более 10 ПДК

The ecological and geological zoning map allows us to obtain an integrated assessment of the territory. Thus, it was revealed that a section close to the petroleum storage depot has extreme ecological conditions due to groundwater pollution at the level of extremal assessment of the environment (IB 2ST). Soils and surface sediments are contaminated at the level of ecological crisis. About 30% of the research area is characterized by uncomfortable environmental conditions due to the crisis state of soils and near-surface sediments. The aquifer is characterized by hazardous and moderately hazardous pollution levels.

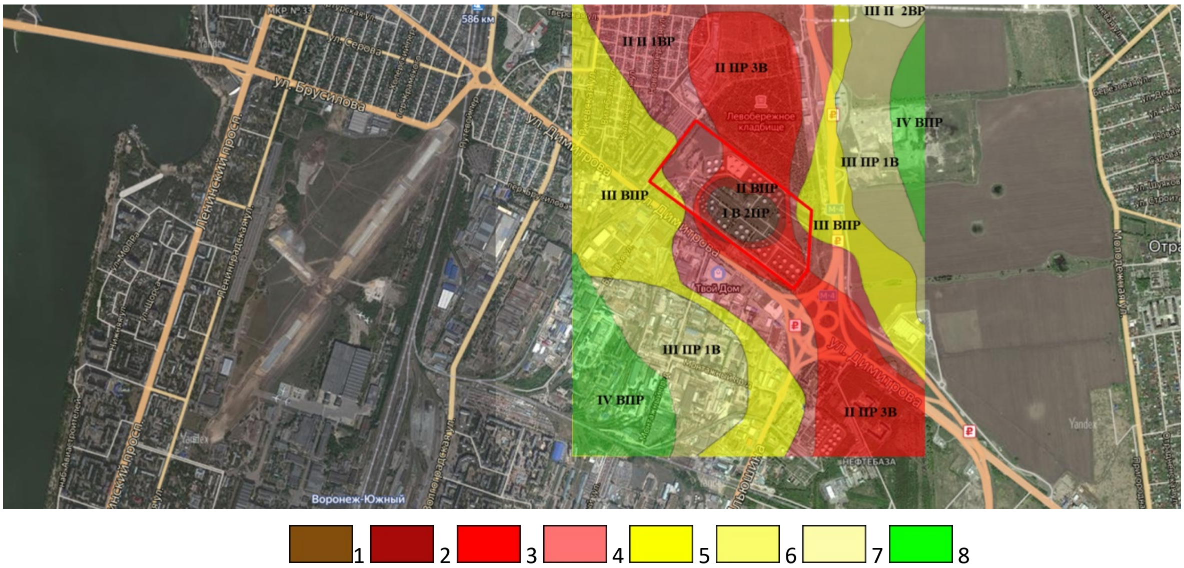

Figure 4. Ecological and geological zoning map of the petroleum storage depot area of first and second levels, Voronezh
Рисунок 4. Карта эколого-геологического районирования района размещения нефтебаз первого и второго уровней, г. Воронеж

More than 40% of the research area can be characterised as constituting an uncomfortable habitat due to the crisis state of soils and near-surface sediments. Hypocomfortable habitat constitutes about 50% of the research area, mainly due to pollution levels of the studied parameters of the ecological and geological system, which correspond ecological risk. The sections located far from the petroleum storage depot can be considered as comfortable habitats.

CONCLUSION

In the framework of the proposed methodology the construction of ecological and geological zoning maps allows us to obtain the following positive results:

1. (a) Integration of information on assessing the status of abiotic and biotic components of the environment. (b) The possibility of map modeling in terms of correlation of the individual components of ecological and geological systems. (c) Identification of the main areas of

environmental protection, harmonious exploitation of the environment.

2. Observation of ecological situation development at various stages of the construction and operation of engineering structures, taking into account the initial state of the ecological and geological system of the construction area and the features of the designed facility.

3. (a) Justification of the system of local environmental monitoring, facilitating the control of developing adverse environmental and geological situations. (b) Assessment of the impact of natural and technogenic sources on facilities under construction.

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AUTHOR CONTRIBUTIONS

Oksana G. Fonova assessed the state of the territory and constructed maps of ecological and geological zoning. Svetlana I. Fonova constructed maps of ecological and geological zoning. Irina I. Kosinova analysed the data obtained. All authors are equally participated in the writing of the manuscript and are responsible for plagiarism, self-plagiarism and other ethical transgressions.

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Оксана Г. Фонова оценила состояния территории, построила карты эколого-геологического районирования. Светлана И. Фонова построила карты эколого-геологического районирования. Ирина И. Косинова проанализировала полученные данные. Все авторы в равной степени участвовали в написании рукописи и несут ответственность при обнаружении плагиата, самоплагиата или других неэтических проблем.

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