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Geological Characteristics of Natural-and-Anthropogenic Landscapes in Oil Extraction Regions of the Republic of Tatarstan

The article studies the geological state of natural-and-anthropogenic landscape complexes in oil extraction regions of the Republic of Tatarstan and describes landscape characteristics on the basis of current ecological condition of natural surface and underground waters and soil. The degree of natural functioning of geological systems transformed due to oil extraction is pointed out on the example of internal landscape forming factors.

Key words: geological state, landscape components, natural-and-anthropogenic landscapes, oil pollution, transformation of environmental properties.

Introduction

Contamination of areas with oil and oil products, substances of the most dangerous and widespread pollutants of the environment (Solnceva, 2002), is one of the important geo-environmental problems. This fully applies to the Republic of Tatarstan, where there are numerous oil and petrochemical industries, and where intensive extraction and refining occurs. From the bowels of the earth has already been withdrawn about 2 billion 900 million tons of oil. Oil production has reached 3493 ha (52% of the total area of the country), and the most common in the oil fields of soils is black earth. According to a 55-year period in the Republic mining 1 ton of oil is accompanied by destruction or contamination of 1-1,3 m³ of land (Gilyazov & Gaysin, 2009).

In the geographical envelope, soil and natural waters are so-called bio-inert subsystems of the landscape. Surface waters are part of the hydrosphere and soils develop as a result of interactions between the atmosphere, hydrosphere, lithosphere and biosphere, as well as being one of the main landscape-forming factors. Therefore the study of the transformation properties of the soil and water pollution as a result of pollution by oil and oil products, at the present stage of development and transformation of geosystems is one of the urgent tasks.

As a result of the degradation of natural and man-made landscapes associated with the extraction and processing of oil, soil, and their constituents lose fertility, their water, physical, chemical and microbiological properties deteriorate, reducing the quality and productivity, and as a consequence, the output of agricultural activity. In addition, the risks of the transformation of the adjacent landscaped environments, such as vegetation, groundwater and surface water, surface layers of the atmosphere appear.

The aim of this work was to study the current ecological state of natural components that make up the landscapes in oil-producing areas of the Republic of Tatarstan and the identification of factors that influence the changes in the properties and functioning of the transformed geosystems.

The objects of study are the surface and ground waters and soil of natural and man-made landscapes, which in accordance with the landscape division of the territory of the Republic of Tatarstan are part Cheremshan-Ikskogo and Nizhnezainskogo sublime landscape areas.

Assessment of impact on geo-ecosystems and action of pollutants such as oil and oil related products in the landscapes is related first of all to the problems of migration and retention in landscape systems. Migratory movements characteristic of oil-component systems are the basis of the forecast of the landscape effects of pollution, the speed of self-purification and recovery of damaged landscapes.

In numerous studies conducted in the oil-producing regions of Russia, it was shown that oil and oil products actively migrate in any of the natural landscape areas and processes related to their migration and metabolism are complex, time-consuming, and depend, in general, on the physical and geographical conditions of the area (Solnceva, 2002; Breus et al., 2005).

The Republic of Tatarstan is located in the east of the East European platform within the Russian Plate – the largest tectonic structure of the platform type, which occupies a large part of European Russia. Absolute heights ranging 53-380 m, the average altitude is 170-180 m relief of the territory of the republic is the typical erosional landscape.

The geological structure is characterized with crystalline basement rocks and platform cover. Devonian and Carboniferous deposits are common, represented by limestones and dolomites, with associated industrial oil bearing area. Permian deposits are widespread; their upper levels often come to the surface. On the territory of the republic the most widespread Upper Permian deposits of Kazan and Tatar layers presented by marine and continental red sandstones, shales, siltstones, calcareous, sandy clay, including red deposits. Quaternary sediments are genetically different, dominated by alluvial gravels, sands, sandy, loam and clay.

In Tatarstan field of fossil fuels and building materials is widely spread. From the economical perspective the most significance for the republic is concentrated in the oil, lignite and coal, shale oil, coal tar and peat. Commercial oil production began in the 50-60 years of XX century. Currently, around 140 large and small oil fields are being developed.

The climate in Tatarstan is temperate continental with warm summers and moderately severe winter, the transition type from wet to semi-wet. Average annual precipitation is 380-500 mm, about 70% of the annual precipitation falls during the warmest and the wettest month of July. The background characteristics of climate, determined by influence of global climate factors, are also determined by micro-climate factors, such as terrain orography and the ratio of land and water surface.

In terms of vegetative surface the territory of the republic

is situated within three geobotanical temperate climatic zone – the zone of mixed forest, deciduous forest zone and zone of forest-steppe, the indigenous vegetation is dominated by coniferous-deciduous and deciduous forests. And only in the south insignificant in areas grassy eco-communities meadow steppes and steppe meadow appear (Atlas lands Tatarstan, 2005).

One of the characteristics of the soil cover of the Republic is the location of its territory within three soil-geographic zones - sod-podzolic soils of southern taiga and mixed forest, gray forest soils and podzolic deciduous forests, leached and typical chernozem steppe. All zonal types of soils are formed in the washing mode and normal moisture-sufficiency. The predominant soil type is black soil, with a total area of 40,6%, grey forests occupy 30,7% of the agricultural land of the Republic, the share of sod-podzolic has 7,7%. Fairly well represented sod-calcareous soils in the whole country, they account for 7% of the total area of agricultural land and calcareous black soil (4%), also found common and meadow chernozem(black earth). Almost all of the soils are heavy grading, clay and heavy species make up 85,1%.

It should be noted that the most common in the oil industry are black earth soils (ashed, leached, typical, carbonate), they are characterized by black or dark grey color and a large humus horizon (40 to 80 cm), with organic content of 6 to 9%.

From the administrative point of view natural and anthropogenic landscapes studied in this research are located in Almetyevsk, Novosheshminsky Zainsk and districts. The geological structure of the studied natural and anthropogenic landscapes is characterized with alluvial and alluvial-diluvial Quaternary, Neogene System (Pliocene) and Permian system (Upper Division) Tatar stage, Kazan tier.

Within the studied landscape profiles are the following geological processes – river and sheet erosion, slope processes, flooding and waterlogging, frost heave.

Sheet erosion is manifested in the form of soil erosion on cultivated areas and steep non greenswarded slopes. The most likely factors that cause this type of erosion are precipitation, wind power and violation of farming activities (plowing along the slope, no belts). River erosion manifests as recycling banks, as a result of erosion and destruction of the rocks under the influence of channel processes and surf.

Within the study area there are processes of flooding and flooding landscapes. On the extent of potential sites of sinking of study area, where there are underground waters, are part to the natural flooding, and those areas where the groundwater is not met – a potentially flooded.

Within the studied landscapes may be a manifestation of frost heaving caused by freezing of the soil, moisture migration, the formation of ice layers and the deformation of the soil skeleton, leading to an increase in the volume of soil and rise it to the surface.

In Tatarstan manifestations of karst processes have been

Defined parameters	Measurement unit	MPC	Ground waters (medium numbers)
Total hardness	mg*eq./l	7	8,5
General mineralization	mg/l	1000	720
Cl⁻	mg/l	350	57
SO₄²⁻	mg/l	500	83
pH	unit	6-9	7,8
Petrochemicals	mg/l	0,1	0,0120

Table 2. Results of chemical analysis of samples from ground water sources.

Defined parameters	Measurement unit	MPC	Surface water (medium numbers)
Total hardness	mg*eq./l	7	10,02
General mineralization	mg/l	1000	763,2
Cl⁻	mg/l	300	65,8
SO₄²⁻	mg/l	100	78,6
pH	unit	6,5-8,5	7,2
Ca²⁺	mg/l	180	112,0
Mg²	mg/l	40	43,9
Oil products	mg/l	0,05	0,0123

Table 3. Results of chemical analysis of surface waters.

registered. Specifically studied area belongs to Iksko-Zayskoy karst area (Ermolaev et al., 2007), but the next section displays karst processes was fixed at about 8 km from the pledged landscape profile. In the study area soluble rocks (limestone) to the studied depth (about 8 m) are not fixed and symptoms of karst, such as craters, pits are not revealed.

The geological structure of landscapes within the profile is due to the complex geological history of the region in the neogene and quaternary time, namely, tectonic processes, that were forming a relief, and the associated processes of sedimentation. In this regard, within the study area allocated undifferentiated complex of alluvial-diluvial and alluvial sediments of Quaternary-making, upper permian sediments.

It should be noted that the geological lithology of the study area is not characterized by consistency of soils on the area and depth of the heterogeneity of their composition and condition. Just within the pledged landscape profile indicated the presence of specific primers, namely, technological, subsidence, swelling and eluvial.

Current ecological state of natural and ground waters. On the territory of Almetyevsk, Zainsk and Novosheshminsky areas numerous underground springs are located, information about which is given in Table 1.

From the results of chemical analysis of water samples of groundwater sources in Table 2, we can draw conclusions about stable exceed in them of total hardness. So, figure of the total hardness of groundwater ranged from 7,2 to 15,6 mg-Eq / L and an average was 8,5 mg-Eq / l. In this regard, water underground sources can be considered as moderately hard and tough. Within other components significant exceeds of the maximum permissible concentrations have not been identified, particularly in terms of residual oil.

The average rate of excess of maximum allowable concentrations of pollutants of ground waters was less than 1, and their

Name of the region	Amount of springs	Possess a legend and historical value		Condition is satisfactory		Are used as source of drinking water		
		Amount	%	Amount	%	Yes	No	Unknown
Almetyevsky	236	4	2	177	75	204	18	14
Zainsky	48	0	0	33	69	42	1	5
Novosheshminsky	28	8	29	20	71	26	2	0

Table 1. Ground waters of studied territories.

status can be assessed as relatively satisfactory, based on the main parameters studied.

Chemical analysis of samples of surface water bodies within the landscape profile are given in Table 3. The data signifies the exceed in the surface waters of the total hardness parameter and calcium content. On the other components no exceeds were found. The measure of the total hardness averaged 10,02 mEq/l. Water streams are considered moderately hard and hard and can be attributed to the type - fresh bicarbonate-magnesium-calcium, salinity 763,2 mg /l.

Since, some of the indicators of oil pollution of water bodies are the content in surface water of chloride, sulphate and residual oil, such studies have been conducted and reported in Table 4. Based on the data, it is possible to conclude the absence in the water samples of chloride ions, sulfate ions, and petroleum products, which indicates absence of flow into the surface water of income to surface water of such contaminants as oil and petroleum products.

Soil conditions and the assessment of the current ecological state of soils. Based on natural and agricultural zoning studied territory of laying landscape profile belongs to the Preduralskoy province steppe zone, district: sublimely ridged loam leached chernozem and meadow-alkaline-black earth. Based on agro-soil zoning the territory relates to the North-eastern and western regions of Zakamye (Atlas of the lands of the Republic of Tatarstan, 2005). Natural agricultural and agro-soil zoning are presented in Table 4.

In areas affected by oil, the analysis of the distribution of the land fund categories and lands, we can note a significant predominance of agricultural land (Table 5), due to the wide spread in the area of highly fertile soil, which are black earth and grey forest. Thus, based on the soil structure, Almetyevsk district refers to the area with a high proportion of black earth (70-90%). And the area is dominated by the most valuable typical black earth. Novosheshminsky area refers to the area with the average proportion of black earth (50-70%), is dominated by leached black earth and dark-grey forest soils. Zainsky area refers to areas with a lower share of black soil (20-50 %), where the soil cover is dominated by gray forest (27-44 %), and brown-gray forest (to 21 %), as well as sod-calcareous soils (up to 8 %).

Based on particle size contents, which widely determines the level of soil resistance towards human impacts, and first of all determines the type of migration of petroleum hydrocarbons in the soil profile, within soil types clay and heavy clay ones dominate, they account for over 76% of the land farms (Table 6).

Erosion processes caused primarily by agricultural use of soil (land disturbance, high plowed, breach technology of agriculture), are one of the strongest negative factors affecting soil fertility and resistance to anthropogenic stress. In terms of area of eroded soils Almetyevsk district is classifies as "restricted-favorable", there, the share of soils prone to erosion make up 10-25% of all arable land, and Novosheshminsky and Zainsky districts are classified as "unfavorable", up to 80% of agricultural lands are considered eroded.

Physics-chemical properties of soil largely determine soil fertility, resistance to anthropogenic loads, the use of topsoil for reclamation activities on marginal lands. According to these properties, most of soils in the study can be attributed to highly fertile and with a high degree of resistance to anthropogenic stress. Since they are characterized by considerable humus horizon (40-70 cm), humus content – 4,8-8,3%, mostly slightly acidic and near neutral, in some cases, slightly alkaline reaction medium. According to its water-physical properties, they are weakly previous and have high-plasticity properties.

Another important factor that allows to assess the sustainability of the landscape to anthropogenic stresses is the location of soils types of relief and the presence in the soil profile of geochemical barriers. In this regard, the most stable are eluvial soil (upland) elementary landscapes possessing sorption, neutral and partly calcareous geochemical barriers. These soils are all subtypes of black earth, as well as turf-carbonate, gray forest and partly meadow

Administrative region	Natural-agricultural zoning			Agro-soil zoning	
	zone	province	region	province	region
Almetyevsky	Forest steppe	Preduralskaya	Sublimely ridged loam leached black earth and meadow-alkaline-black earth	Zakamye	North-Eastern Zakamye
Zainsky	Forest steppe	Preduralskaya	Sublimely ridged loam leached black earth and meadow-alkaline-black earth	Zakamye	North-Eastern Zakamye
Novosheshminsky	Forest steppe	Preduralskaya	Sublimely ridged loam leached black earth and meadow-alkaline-black earth	Zakamye	Western Zakamye

Table 4. Natural-agricultural and agro-soil zoning of administrative regions of the studied territory.

Administrative region	Total area, thousand ha	Land with agricultural purpose, thousand ha	Populated land, thousand ha	Industrial land, thousand ha	Land with forest fund, thousand ha	Reserve land, thousand ha
Almetyevsky	249,9	155,4	8,348	14,1	76,5	-
Zainsky	184,2	122,4	5,059	3,0	54,5	-
Novosheshminsky	131,7	111,4	5,274	1,3	14,5	-

Table 5. The distribution of the land fund of administrative regions into categories and wetlands.

Granulometric composition													
Clay		Heavy-loamy		Medium-loamy		Lightly-loamy		Sandy loam		Sandy		Soils not classified by granulometric composition	
ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
Almetyevky region													
67,467	56,6	29,442	24,7	6,675	5,6	7,391	6,2	6,437	5,4	0,834	0,7	0,954	0,8
Zainsky region													
7,513	6,5	87,669	75,9	11,503	10,0	4,105	3,5	0,852	0,74	0,000	0,8	3,830	3,3
Novosheshminsky region													
3,753	3,6	94,877	89,3	5,124	4,8	0,335	0,3	0,049	0,06	0,021	0,03	2,002	1,9

Table 6. Granulometric composition of studied territory soil.

Parameters	Measurement unit	MPC	The background concentration of pollutants in the soil	Soils (medium numbers)
pH	unit.	Not norm.	-	7,5
Cl⁻	Mg/kg	360,0	-	26,5
SO₄²⁻	Mg/kg	160,0	-	109,8
Petrochemicals	Mg/kg	1500	-	103,7
Lead	Mg/kg	130,0	20	0,0152
Cadmium	Mg/kg	2,0	0,24	0,0010
Arsenic	Mg/kg	10,0	5,6	0,0223
Copper	Mg/kg	132,0	25	0,8271
Zink	Mg/kg	220,0	68	0,2212
Nickel	Mg/kg	80,0	45	0,1798
Mercury	Mg/kg	2,1	0,2	Not found
Chrome	Mg/kg	0,05	-	0,0124

Table 7. Results of soil samples chemical analysis.

Region	Element concentration, mg/kg soil				
	Cu	Zn	Pb	Cr	Ni
Almetyevsky	44	63	16	230	58
Novosheshminsky	42	66	16	190	59

Table 8. Average concentration of heavy metal in oil-producing regions of republic of Tatarstan.

Categories of soil contamination	Total index of pollution Zc	Characteristics of soil pollution
Admissible	<16	Chemical content of the soil exceed the background content, but no more than MPC
Moderately dangerous	16-32	Chemical content in the soil exceeds its MPC along with limited water migration and air migration danger index, but it is less than admissible level translocation indicator
Dangerous	32-128	Chemical content in soil exceed its MPC along with limited translocation hazard indicator
Extremely dangerous	>128	Chemical content in soil exceeds MPC in soil based on all hazard indicators

Table 9. Categories of soil contamination, depending on the size of the total index of chemical pollution.

black earth. Place a sink for pollutants are geochemically and subaqueous superaqual elementary landscapes, which are mainly the sorption and carbonate geochemical barriers. These locations are confined part of the meadow-black earth, meadow marsh calcareous alluvial sod acidic and calcareous soils. As shown above, the soil cover of the study territory is dominated by black earth leached, typical black soil of the residual carbonate, gray forest and dark-gray forest soils related to the filler surface water dividers, i.e. to eluvial landscapes.

In order to assess the general condition of the soil cover natural and man-made landscapes of oil-producing areas, soil environment has been studied. Soil samples were taken along the trajectory of landscape structure. Soil sampling performed with the vertical structure, the heterogeneity of soil, topography and type of land as well as the placement of oil facilities in the locality. Results of analysis of soil samples presented in Table 7 show that the content of almost all studied components does not exceed the maximum permissible concentration in the soil. Thus, the oil content in the samples of soil samples varies from 15,3 to 192,0 mg /kg, with an average

of 103,7 mg /kg, and the maximum permissible concentrations were not observed. Therefore, the level of soil contamination in the study area on the oil content can be attributed to the allowable.

Monitoring of soil contamination with toxic substances of industrial origin, which include heavy metals is also a key part of monitoring the state of the environment in the areas of mining and oil refining.

The main sources of heavy metals in the soil of the landscape is their loss with precipitation, the transfer of surface water, as well as to the soil and groundwater runoff

Thus the concentration of heavy metals in soils of studied landscapes does exceed the maximum allowable concentrations for clay, loam and sandy loam soil types with pH>5,5. Approximate values of the background of gross forms of metals for black earth for zinc is 68 mg / kg, cadmium – 0,24 mg / kg, lead – 20 mg / kg, mercury – 0,2 mg / kg, copper – 25 mg / kg, nickel – 45 mg / kg, arsenic – 5,6 mg / kg, respectively.

The content of heavy metals in the soil samples of studied landscapes in most cases is well below background values (Table 7).

Within the present study, the level of chemical contamination of soil in areas of oil production has been defined.

To characterize the level of pollution of the landscape profile the total pollution index Z_c is used, which is defined as the ratio of fixed content element to its background value. As background level concentrations of chemicals regional rates have been used of soil in relation of content within them of Cu, Zn, Pb, Ni. The average concentration of heavy metals in soil of the studied area is presented in Table 8 (State Report, 2010).

Summary indicator of chemical pollution (Z_c) characterizes the degree of chemical contamination of soil and ground of the studied area with harmful substances of different classes of risk. Intervals of the indicator of chemical pollution and the corresponding categories of soil contamination are shown in Table 9. The results of calculations of the total soil pollution index (Z_c), which were based on analytical data of heavy metals in selected soil samples were ≤16 ($Z_c \leq 16$). This indicates the level of soil contamination of the territory as admissible.

Conclusion

Therefore, the results of the study give evidence of the geo-environmental conditions and specific needs of natural and man-made landscapes in areas of oil production. Absence of a substantial transformation of environmental condition and properties of domestic natural components within the system landscape, in the presence of anthropogenic impact can be noted.

Thus, concentration of pollutants in the soil, surface and ground waters of the studied landscape does not exceed the maximum permissible value, which characterizes the natural stable functioning of natural-territorial areas, which have been converted during economic activity.

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