SECTION III. RESOURCE SAVING

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Environmental assessment of the state of the underground lake Kokzhide, taking into account the impact of the activities of oil producing enterprises

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Abstract

Nowadays, Kazakhstan is experiencing a shortage of fresh groundwater resources, which in the future may lead to a complete depletion of this type of resources. One of the most promising sources of drinking fresh water in our country is the Kokzhide groundwater field, the state of which has deteriorated under the influence of oil production enterprises. The aim of the research was to conduct an environmental assessment of the state of the underground lake Kokzhide, taking into account the impact of the activities of oil producing enterprises, as well as to develop practical recommendations to minimize the harmful effects of subsoil users. Field and laboratory research methods were used in the work. Assessment of the state of groundwater at the Kokzhide deposit consists in a comparative analysis and processing of the results obtained during laboratory studies of water samples, taking into account the data of field route observations of the territory of the studied object, made in October 2019. In addition, the average intensity of pollution by oil products and the degree of natural protection of groundwater were chosen as the main criteria for assessing the ecological state of groundwater. The results of the research have shown increased concentrations of oil products in the content of the underground water. A comparative analysis of the obtained data shows the correlation of the content of oil products with the depth of observation wells. The greatest excess of the maximum permissible concentration of oil products in groundwater was observed mainly in the north-western part of the territory of the Kokzhide groundwater field, in the areas of intensive production of hydrocarbons. The high content of phenols in groundwater is the result of the impact of the activities of oil producing enterprises, as a result of which oil products, which contain phenol, are introduced into the aquifers. At the same time an increase in the content of total iron in the Kokzhide underground waters was found, which may result from the processes of oxidation and corrosion of well filters and casing pipes. Moreover, the assessment of the natural protection intensity of the groundwater field it has shown that the natural hydrogeological conditions of the site give rise to a high risk of introducing oil products into the aquifers, resulting in the formation of extensive pollution.

Keywords: groundwater field, hydrogeological environment, environmental assessment.

Аннотация

В настоящее время Казахстан испытывает дефицит ресурсов пресных подземных вод, что в будущем может привести к полному истощению этого вида ресурсов. Одним из наиболее перспективных источников питьевой пресной воды в нашей стране является Кокжидинское месторождение подземных вод, состояние которого ухудшилось под влиянием нефтедобывающих предприятий. Целью исследования было проведение экологической оценки состояния подземного озера Кокжиде с учетом воздействия деятельности нефтедобывающих предприятий, а также разработка практических рекомендаций по минимизации вредного воздействия недропользователей. В работе использовались полевые и лабораторные методы исследования. Оценка состояния подземных вод месторождения Кокжиде заключается в сравнительном анализе и обработке

результатов, полученных в ходе лабораторных исследований проб воды, с учетом данных полевых маршрутных наблюдений за территорией изучаемого объекта, произведенных в октябре 2019 года. Кроме того, в качестве основных критериев оценки экологического состояния подземных вод были выбраны средняя интенсивность загрязнения нефтепродуктами и степень естественной защищенности подземных вод. Результаты исследований показали повышенные концентрации нефтепродуктов в составе подземных вод. Сравнительный анализ полученных данных показывает зависимость содержания нефтепродуктов от глубины залегания наблюдательных скважин. Наибольшее превышение ПДК нефтепродуктов в подземных водах наблюдалось в основном в северо-западной части территории Кокжидинского месторождения подземных вод, в районах интенсивной добычи углеводородов. Высокое содержание фенолов в подземных водах является результатом воздействия деятельности нефтедобывающих предприятий, в результате которой в водоносные горизонты поступают нефтепродукты, содержащие фенол. В то же время установлено увеличение содержания общего железа в подземных водах Кокжиде, что может быть следствием процессов окисления и коррозии скважинных фильтров и обсадных труб. Кроме того, оценка интенсивности природной защиты месторождения подземных вод показала, что естественные гидрогеологические условия участка обуславливают высокий риск поступления нефтепродуктов в водоносные горизонты, что приводит к образованию обширных загрязнений.

Ключевые слова: месторождение подземных вод, гидрогеологическая среда, экологическая оценка.

Introduction

Today, the problem of a shortage of fresh water in Kazakhstan is becoming more and more tangible, which is due to the uneven distribution of fresh water sources throughout the country, a low level of priority in the formation of water policy and the raw material orientation of the economy in relation to oil and gas production.[1]

Oil production is a complex industrial process, at all stages of which there is a technogenic transformation of the ecosystem of the explored region. One of the natural components affected by oil production is natural groundwater.

A striking example of the manifestation of this type of technogenic impact is the Kokzhide deposit, the largest in terms of reserves of underground fresh water in Kazakhstan, located on the territory of the Aktobe region. [3][4] It is known that the Kokzhide groundwater deposit is included in the list of environmental protection objects of special ecological, scientific and cultural significance, as well as in the list of objects of the state natural reserve fund of republican significance. However, at the moment, the underground waters of Kokzhide are under pressure from oil producing enterprises.

A distinctive feature of the field is the layered arrangement of aquifers extending to a depth of 150 m, under which, at a depth of 492 m, the post-salt formations of the oil field lie, and even lower - subsalt oil formations located at a depth of 3000-4000 m. [5] Thus, the close proximity of oil and aquifers contributes to the emergence of a high risk of oil pollution during oil production.

The consequence of the oil impact was a significant contamination of groundwater in Kokzhide, which was repeatedly confirmed by the results of monitoring studies carried out by the Department of Management and Development of the Aktobe region in the period from 2008 to 2018. In particular, according to the results of monitoring in 2010, it was established that the MPC of oil products was exceeded by up to 41 times, which indicates the need to take measures to solve this problem. Thus, the study of the ecological state of groundwater in Kokzhide is very urgent.

The aim of the work was to conduct an environmental assessment of the state of the underground lake Kokzhide, taking into account the impact of the activities of oil producing enterprises, as well as to develop practical recommendations to minimize the harmful effects of subsoil users. The object of research is the underground waters of the Kokzhide deposit.

The scientific novelty of the work lies in the environmental assessment of the state of groundwater in Kokzhide for 2019 with the compilation of a comparative analysis of the chemical composition of groundwater and its dynamics by seasons and over 10 years. In the course of the study, facts of exceeding the maximum permissible concentration of pollutants in the composition of groundwater were revealed and a correlation was established between changes in the content of oil products with changes in the depth of observation hydrogeological wells. In addition, for the first time in the study area, an assessment was made of the degree of natural protection of groundwater in Kokzhide from surface pollution.

Methods

Field and laboratory research methods were used in the work. Field work was carried out in accordance with the Program for monitoring ground and surface waters of the "Sands Kokzhide" facility (hereinafter referred to as the Program), developed by "Aliya and Co" LLP and approved by the Department of Natural Resources and Environmental Management of the Aktobe region. The visit was carried out jointly with employees of LLP "Aliya and Co", as well as with employees of the Department of Ecology of the Aktobe region.

In accordance with the Program, autumn observations of surface and ground waters of the "Sands of Kokzhide" object were carried out, consisting of two stages:

- preparatory work: at this stage, the initial collection of information on the object under study was carried out, which consisted in the analysis of earlier studies, as well as stock reference materials and regulatory documents, the study and verification of the extracted materials;
- field research: work was carried out to measure the level of groundwater, take water samples [6] and preserve them, as well as route surveys of the study area. Field research was carried out in October 2019.

In accordance with the Technical Specification of the Program, groundwater monitoring is carried out through a network of observation wells that monitor the state of groundwater, both on the territory of the Kokzhide sand massif and on its border areas. The wells are oriented towards the upper part of the productive aquifer and are located along the perimeter of the massif in areas with an increased density of anthropogenic load, that is, on the path of possible inflow of contaminants to the groundwater field. The 17 wells were included in the observation network for monitoring groundwater in autumn 2019.

Route surveys were carried out in the contract areas of oil-producing enterprises within the sandy massif. The main objective of the route survey was to visually identify areas susceptible to surface contamination with oil products. During the route survey, attention was paid to the state of the soil and vegetation cover, the degree of its oppression and degradation under the influence of anthropogenic activity.

Within the Kokzhide groundwater field and near it, there are 12 contract territories of eight oil-producing enterprises. Among them, 4 enterprises own mining leases and produce oil: CNPC-Aktobemunaigas JSC, KMK-Munai JSC, Firma Ada Oil LLP, Kazakhoil-Aktobe LLP.

During the route surveys, oil contamination of the soil cover was visually identified. The consequence of the introduction of petroleum products to the surface of the soil cover may be their subsequent infiltration into the groundwater, and then into the pressurized groundwater.

Laboratory studies were carried out in the laboratories of the Department of Ecology in the Aktobe region and the Department of Ecology in the city of Nur-Sultan. According to the Groundwater Monitoring Program, studies were carried out on 26 components, among which the following were determined by laboratory research methods.

- 1) Physical and chemical indicators: suspended solids, hardness, dry residue, Cl^- , SO_4^{2-} , HCO_3^- , Na^+ , K^+ , Ca^{2+} , Mg^{2+} .
- 2) Indicators of pollutants: oil products, BOD_5 [7], phenols, NH_4^+ , nitrites, nitrates, synthetic surfactants, fluorides, total iron.
- 3) Heavy metals (Ni, Co, Cd, Cu, Pb, Zn). [8][9].

Each indicator in water samples from 17 wells was determined 3 times, followed by the calculation of the average value of the results of three analyzes for each indicator. In general, for all indicators for water samples taken from 17 wells, 1326 laboratory analyzes were performed.

Results

To assess the water quality by hydrochemical indicators, the results obtained were compared with the values of the maximum permissible concentrations of the determined components in accordance with the Sanitary Rules, approved by the Order of the Minister of National Economy of the Republic of Kazakhstan dated March 16, 2015 No. 209. The results of physical and chemical indicators are reflected in Table 1, indicators of pollutants - in Table 2, heavy metals - in Table 3.

Table 1

Physical and chemical indicators

№ of the well	Physical and chemical indicators (mg/ dm³)										
	Suspend d solids	pH	Dry residu e	Hardness *	HCO ₃ -	Cl ⁻	SO ₄ ²⁻	Na ⁺	K ⁺	Ca ²⁺	Mg ²⁺
MP C	-	6-9	1000	7	-	350	500	-	-	-	-
4M	34,7	7,6 3	121,6	1,3	52,8	14, 7	23,2	6,5	1, 5	18	4,9
5M	41,5	7,3 4	311	4	175,4	15	36,8	7,9	1, 8	65,2	8,9
6M	31,2	6,5 6	343,6	3,7	187,3	28, 2	39,4	18, 5	2	58,5	9,7
7M	28,4	6,4 5	170	2,3	68,7	11	33,8	12, 4	1, 8	36,7	5,6
8M	42,3	6,3 2	247,7	2,9	118	25	48	4,7	1, 5	39,3	11,2
9M	38,7	7,5 9	318,6	2,5	176,4	39, 3	47,5	9,2	1, 8	34,9	9,5
10M	23,5	6,9	352,2	3,7	215,2	16, 8	42,3	7,6	1, 2	61,3	7,8
11M	36,6	7,6 5	322,6	4,1	186,5	15, 8	36,8	6,9	1, 6	63,7	11,3
12M	24,3	6,7 2	176,3	1,5	68,2	16	43,2	15, 1	1, 8	23,8	8,2
13M	37,9	7,8 7	315,2	2,6	211,8	11, 4	27,3	15, 9	1, 7	35	12,1
14M	31,5	6,5 3	304,2	2,8	196,5	12, 3	26,8	15, 7	1, 6	43	8,3
15M	43,2	7,2 8	221,9	1,9	133,2	12, 5	14,2	28, 3	1, 8	25,2	6,7
11N	33,8	6,6 5	164,6	1,2	68,9	19, 3	38,3	17, 4	1, 5	11,3	7,9
14N	37,5	6,3 4	189,5	1,8	87,8	15	35,2	19, 3	1, 4	22,3	8,5
16H	30,4	6,3 9	130,5	1,2	75	18, 2	5,6	8,2	1, 3	17	5,2
17H	37,9	7,7 8	261,2	4,9	98,8	31, 5	41,6	12, 6	3, 5	34,5	38,7
21N	46,8	7,2 6	116,4	1	58,3	12, 6	15,3	12, 8	1, 9	9	6,5
* mg-eq/dm³											

According to the analysis results given in Table 1, the total mineralization of underground waters of Kokzhide is equal to 239.2 mg / dm³ on average, which means that they are fresh. Water hardness is in the range of 1-4.9 mg-eq / dm³ and does not exceed 2.6 on average. According to the average hardness, the Kokzhide waters are soft. The hydrogen index is in the range of 6.32-7.87 and does not exceed 7 on average, which corresponds to a neutral environment. Thus, the values of the physicochemical indicators of the quality of groundwater are generally within the normal range.

Table 2

Indicators of pollutants

<i>Nº of the well</i>	<i>Indicators of pollutants (mg/ dm³)</i>								
	<i>NH₄⁺</i>	<i>NO₂⁻</i>	<i>NO₃⁻</i>	<i>Fe total</i>	<i>Synthetic surfactants</i>	<i>Phenols</i>	<i>Oil products</i>	<i>Fluorides</i>	<i>BOD₅[*]</i>
<i>MPC</i>	2,0	3,0	45	0,3	0,5	0,001	0,1	1,5	6,0
<i>4M</i>	0,1	0,13	3,59	0,41	<0,025	0,0013	0,35	0,32	2,2
<i>5M</i>	0,2	0,025	0,14	0,44	<0,025	0,0012	0,22	0,17	2,0
<i>6M</i>	0,1	0,002	0,12	0,42	<0,025	0,0013	0,41	0,23	2,4
<i>7M</i>	0,2	0,015	0,35	0,35	<0,025	0,0012	0,23	0,58	2,0
<i>8M</i>	0,20	0,018	0,28	0,34	<0,025	0,0011	0,2	0,59	1,5
<i>9M</i>	0,1	0,011	0,25	0,33	<0,025	0,0008	0,18	0,46	1,6
<i>10M</i>	0,13	0,022	0,26	0,34	<0,025	0,0009	0,18	0,54	1,8
<i>11M</i>	0,1	0,038	0,11	0,33	<0,025	0,0011	0,21	0,28	1,3
<i>12M</i>	0,1	0,025	0,24	0,32	<0,025	0,0012	0,28	0,21	1,2
<i>13M</i>	0,1	0,012	0,12	0,46	<0,025	0,0012	0,2	0,81	1,9
<i>14M</i>	0,22	0,003	0,25	0,5	<0,025	0,0014	0,42	0,75	2,5
<i>15M</i>	0,21	0,011	0,84	0,4	<0,025	0,0015	0,26	0,23	2,8
<i>11N</i>	0,1	0,003	0,19	0,41	<0,025	0,0014	0,32	0,41	2,3
<i>14N</i>	0,1	0,011	0,27	0,46	<0,025	0,0013	0,44	0,22	2,4
<i>16H</i>	0,1	0,018	0,11	0,32	<0,025	0,0008	0,12	0,21	1,2
<i>17H</i>	0,1	0,004	0,32	0,52	<0,025	0,0014	0,35	0,27	2,5
<i>21N</i>	0,1	0,014	1,4	0,4	<0,025	0,0013	0,26	0,24	1,9
<i>* mg-O₂/dm³</i>									

According to the data in Table 2, the content of ammonium nitrogen, nitrates and nitrites, as well as the BOD₅ values are within the normal range, which indicates a low content of easily oxidizable organic compounds in the composition of groundwater, characteristic of biological pollution. However, there is a significant excess of the maximum permissible concentrations of iron, oil products and phenols in the composition of groundwater.

Elevated concentrations of iron are noted in all wells and vary within the range of 0.32-0.52 mg / dm³ with an MPC of 0.3 mg / dm³, and correspond to an excess of 1.1-1.6 MPC. A high

content of oil products is also noted in all wells and is in the range of 0.12-0.44 mg / dm³, which exceeds the MPC by 1.2-4.4 times. The maximum permissible concentration of phenols was exceeded by 1.1-1.5 times and was noted in water samples from 14 wells. The values of other indicators, such as synthetic surfactants and fluorides, comply with the standards. The content of heavy metals in the composition of groundwater is within the permissible limits.

Table 3

Heavy metals

<i>№ of the well</i>	<i>Heavy metals (mg/ dm³)</i>					
	<i>Ni</i>	<i>Cu</i>	<i>Co</i>	<i>Cd</i>	<i>Pb</i>	<i>Zn</i>
<i>MPC</i>	<i>0,1</i>	<i>1,0</i>	<i>0,1</i>	<i>0,001</i>	<i>0,03</i>	<i>5</i>
<i>4M</i>	<i>0,001</i>	<i>0,001</i>	<i>0,001</i>	<i>0,0001</i>	<i>0,001</i>	<i>0,001</i>
<i>5M</i>	<i>0,001</i>	<i>0,008</i>	<i>0,001</i>	<i>0,0001</i>	<i>0,001</i>	<i>0,0113</i>
<i>6M</i>	<i>0,001</i>	<i>0,033</i>	<i>0,001</i>	<i>0,0001</i>	<i>0,001</i>	<i>0,0112</i>
<i>7M</i>	<i>0,001</i>	<i>0,064</i>	<i>0,001</i>	<i>0,0001</i>	<i>0,001</i>	<i>0,006</i>
<i>8M</i>	<i>0,001</i>	<i>0,065</i>	<i>0,001</i>	<i>0,0001</i>	<i>0,001</i>	<i>0,005</i>
<i>9M</i>	<i>0,001</i>	<i>0,038</i>	<i>0,001</i>	<i>0,0001</i>	<i>0,001</i>	<i>0,001</i>
<i>10M</i>	<i>0,001</i>	<i>0,032</i>	<i>0,001</i>	<i>0,0001</i>	<i>0,001</i>	<i>0,001</i>
<i>11M</i>	<i>0,001</i>	<i>0,003</i>	<i>0,001</i>	<i>0,0001</i>	<i>0,001</i>	<i>0,001</i>
<i>12M</i>	<i>0,001</i>	<i>0,001</i>	<i>0,001</i>	<i>0,0001</i>	<i>0,001</i>	<i>0,001</i>
<i>13M</i>	<i>0,001</i>	<i>0,001</i>	<i>0,001</i>	<i>0,0001</i>	<i>0,001</i>	<i>0,035</i>
<i>14M</i>	<i>0,001</i>	<i>0,001</i>	<i>0,001</i>	<i>0,0001</i>	<i>0,001</i>	<i>0,041</i>
<i>15M</i>	<i>0,001</i>	<i>0,031</i>	<i>0,001</i>	<i>0,0001</i>	<i>0,001</i>	<i>0,001</i>
<i>11N</i>	<i>0,001</i>	<i>0,001</i>	<i>0,001</i>	<i>0,0001</i>	<i>0,001</i>	<i>0,001</i>
<i>14N</i>	<i>0,001</i>	<i>0,031</i>	<i>0,001</i>	<i>0,0001</i>	<i>0,001</i>	<i>0,001</i>
<i>16H</i>	<i>0,001</i>	<i>0,001</i>	<i>0,001</i>	<i>0,0001</i>	<i>0,001</i>	<i>0,001</i>
<i>17H</i>	<i>0,001</i>	<i>0,001</i>	<i>0,001</i>	<i>0,0001</i>	<i>0,001</i>	<i>0,001</i>
<i>21N</i>	<i>0,001</i>	<i>0,032</i>	<i>0,001</i>	<i>0,0001</i>	<i>0,001</i>	<i>0,006</i>

Discussion

Assessment of the state of groundwater at the Kokzhide deposit consists in a comparative analysis and processing of the results obtained during laboratory studies of water samples, taking into account the data of field route observations of the territory of the studied object, made in October 2019. In addition, the average intensity of pollution by oil products and the degree of natural protection of groundwater were chosen as the main criteria for assessing the ecological state of groundwater. Underground waters of Kokzhide by organoleptic characteristics and properties of water (smell, taste, color and turbidity) meet the Sanitary Rules. The value of the chromaticity index corresponds to 5 degrees, the turbidity is equal to 1.5 units of turbidity for kaolin, and the smell and taste are estimated at 2 points each [10]. The values of the concentrations of the main ions in the composition of water are much lower than the maximum permissible (Figures 1, 2).

Figure 1. The main anions concentration

In accordance with Figure 1, hydrocarbonates (HCO_3^-) prevail among the main anions in the Kokzhide groundwater composition. Hydrocarbonate ion is distributed mainly in fresh underground or brackish waters. The entry of hydrocarbonate ion into groundwater occurs naturally as a result of leaching of the host rocks in the presence of carbon dioxide in the water. Thus, the predominance of hydrocarbonates in the composition of groundwater indicates the corresponding lithological composition of rocks of the aquiferous complex, including limestone, dolomite and marl rocks.

Figure 2. The main cations concentration

According to Figure 2, calcium ions prevail among the main cations in the Kokzhide groundwater composition. In general, calcium ions are a common component in the composition of waters of various salinity. In particular, in fresh groundwater, the calcium ion is found in combination with HCO_3^- and SO_4^{2-} ions.

The introduction of these ions into groundwater is also due to the action of natural factors and mainly occurs as a result of the weathering of igneous rocks, as well as the leaching of limestone, dolomite rocks, gypsum, and anhydrite. In addition, calcium ions can enter groundwater due to ion exchange with the absorbed complex of clay rocks, including kaolinite rocks, montmorillonite, and other layered aluminosilicates. Thus, according to the ion-salt composition in accordance with the classification of O.A. Alekin underground waters of Kokzhide mainly refer to hydrocarbonate calcium waters.

According to the results shown in Table 2, exceeding the maximum permissible concentrations of the following polluting components were found in the composition of groundwater in Kokzhide: oil products, iron and phenols.

Figure 3. Concentration of oil products

In accordance with Figure 3, increased concentrations of oil products were detected in samples taken from all 17 wells. Concentration values vary from 0.12 to 0.44 mg / dm³, with an MPC of 0.1 mg / dm³, which corresponds to an excess of 1.2-4.4 MPC.

Analysis of the data shown in Figure 3 shows the correlation of the content of oil products with the depth of observation wells, according to which an increase in the concentration of oil products along with the depth was established.

Thus, in the samples of 7 wells, the depth of which ranges from 19 to 29 m, an excess of the concentration of oil products of 2.8-4.4 MPC was recorded. These wells include: 4M, 11N, 17H, 12M, 6M, 14N, 14M. The share of these wells is 41.2% of the total.

In the samples of 10 wells, the depth of which does not reach 19 m, the concentration of oil products varies within the range of 0.12-0.26 mg / dm³. These wells include: 16H, 10M, 13M, 11M, 15M, 5M, 21N, 9M, 8M, and 7M.

The formation of oil pollution at great depths can be the result of the overflow of oil products in the annulus of oil wells due to corrosion in the production strings or damage to the Portland cement of the casing strings, the function of which is to protect aquifers from the penetration of oil products [11].

The main reason for damage to the tightness of cementation and the formation of corrosive processes is the long-term operation of oil wells under aggressive exposure to a humid environment, which is also noted in the mining allotments of KMK-Munai LLP and SNPS-Aktobemunaigas LLP, whose oil wells are in operation from 1996-1997.

Wells of oil fields that are in the middle and late stages of production can experience uncontrolled flows of oil products through the annular space from the high-pressure area to the lower-pressure area, i.e. into the upstream fresh groundwater.

At the same time, damage to the cement ring is often the result of geological, technological and other factors. Thus, violations of the production process technology lead to the formation of holes and cracks in the cement stone, as well as in the zones of contact of the cement stone with the casing and the rock, which leads to the free penetration of formation fluids into the area of aquifers [12].

In general, the greatest excess of the maximum permissible concentration of oil products in groundwater is observed mainly in the north-western part of the territory of the Kokzhide groundwater field, in the areas of mining allotments of oil producing enterprises carrying out intensive production of hydrocarbons: KMK-Munai LLP, LLP SNPS-Aktobemunaigas and Firm Ada Oil LLP.

This is due to the accumulation of a large number of oil production wells of these enterprises located in the areas of occurrence of the Upper Quaternary-modern alluvial aquifer (a QIII-IV),

located in the area of the Temir River floodplain, as well as above the floodplain river terraces. This aquifer is characterized by a low degree of natural protection due to the partial absence of a waterproof roof, as well as the presence of many hydrogeological windows that form a hydraulic connection with the groundwater of the Albion complex [13].

In such conditions, pollution could arise in connection with the occurrence of oil spills on the surface of the soil cover, which subsequently leads to unhindered infiltration of oil products into the aeration zone and further into the aquifers. This is confirmed by photographs taken during the route surveys of the contract area of KMK-Munai LLP, where the fact of a breach of the production process technology and the occurrence of an accidental spill around well No. 714 of the Kokzhide field was established.

Thus, the natural hydrogeological conditions of the site give rise to a high risk of introducing oil products into the aquifers, resulting in the formation of extensive pollution.

In addition, there is a gradual decrease in the concentration of oil products in the direction from the north-west to the south-east of the Kokzhide field. The smallest excess of MPC for oil products was found in the samples of wells mainly located in the southeastern part of Kokzhide, in areas with a relatively lower technogenic load. These wells include 9M, 10M and 16N.

So, the 9M well is located on the territory of the geological allotment of the enterprise "AOC Trade Group" LLP, the industrial activity of which is currently suspended. The 10M well is located on the territory of the geological allotment of Urikhtau Operating LLP, which carries out periodic exploration work. The 16H well is located outside the contract territories of subsoil users.

The reasons for such a distribution of concentrations of oil products may be associated with the features of the terrain and the hydrogeological structure of aquifers, characterized by the complexity of the hydraulic network, which prevents the uniform distribution of pollutants that have penetrated into the aquifer [14].

Figure 4. Total iron concentration

In addition, the results of laboratory analyzes of selected groundwater samples, shown in Figure 4 above, indicate a widespread excess of the maximum permissible concentration of iron in the composition of groundwater in Kokzhide. At the same time, there is a uniform distribution of increased concentrations of iron over the territory of Kokzhide and the absence of their significant fluctuations. The values of high concentrations of iron in the Kokzhide underground waters are in the range from 0.32 to 0.52 mg / dm³, which corresponds to an excess of 1.1-1.73 MPC.

In general, excess of MPC for total iron was found in all wells. Separately, wells 9M, 11M, 12M and 16N should be noted, in the water samples of which the concentration of iron is close to the threshold level of the maximum permissible. The increased concentrations of total iron in the composition of groundwater are explained by the high prevalence of this element in the earth's crust, as well as by its active migration from the soil cover to the aquifers, the intensity of which

increases in a humid environment [15]. Thus, the ingress of iron into groundwater mainly occurs from the host rocks, which is due to natural causes.

In addition, an increase in the content of total iron in the Kokzhide underground waters may result from the processes of oxidation and corrosion of well filters and casing pipes, which is confirmed by the results of the analyzes, which show the greatest excess of the MPC for this element in samples from observation wells located near a large accumulation of oil production wells. Such excesses are noted in the samples of wells 17H, 21N, 14N, 5M, 6M, located on the territory of the mining allotment of KMK-Munai LLP, and wells 13M, 14M, 11N, 15M, 4M, located in the mining allotment of Firma Ada Oil LLP ".

Figure 5. Phenol's concentration

Also, according to the results of the laboratory studies, the excess of the maximum permissible concentrations of phenols in the composition of groundwater was revealed (Figure 5). The high content of phenols in groundwater is the result of the impact of the activities of oil producing enterprises, as a result of which oil products, which contain phenol, are introduced into the aquifers [16]. Excess of MPC for phenols was recorded in water samples from 14 wells, except for wells 9M, 10M and 16N. Thus, there is a correlation between the content of oil products in the composition of groundwater, which is typical for oil pollution.

Figure 6. Comparative analysis of the concentration of oil products by seasons: spring, summer and autumn, 2019

The above results of field and laboratory studies reflect the state of groundwater in Kokzhide in the autumn period of monitoring work, which gives an incomplete picture of the mechanisms of pollution (Figure 6).

In this regard, in order to identify the nature and dynamics of the distribution of oil pollution during the year, I received data from monitoring studies of the Department of Ecology in the Aktobe region for the spring and summer periods of 2019. A comparative analysis of the content of oil products for three seasons of 2019 is shown in Figure 6.

Monitoring research data for 2019 show an increase in the concentration of oil products in the spring. This dynamic is explained by the influence of climatic conditions and seasonal atmospheric phenomena in the region under study.

According to the data of regime observations obtained from the meteorological station of the city of Aktobe, a stable snow cover is established in early December, reaching a maximum height of 38 cm in the first ten days of March. From the second half of March, the air temperature begins to rise, which leads to the appearance of melt water accumulating in the relief depressions.

The low level of evaporation, characteristic of the spring-autumn period of this region, promotes the infiltration of a greater proportion of melt water and atmospheric precipitation into the aquifers, as a result of which the infiltration of oil products accumulated in the aeration zone during outflow during leaks from wells occurs [17].

Figure 7. Dynamics of the content of oil products in groundwater in Kokzhide for 2009-2019

Figure 7 shows the dynamics of the average values of the concentration of oil products in groundwater in Kokzhide for 2009-2019, compiled according to the monitoring studies of the Department of Ecology in the Aktobe region.

Analysis of the data shows a gradual decrease in the average concentration of oil products in water. Separately, it should be noted the results for 2010, for which a sharp increase in the average concentration of oil products is observed, which indicates an emergency situation, as a result of which a significant volume of oil products was spilled. Minor increases were noted in 2015 and 2017, which also indicates the occurrence of emergency leaks.

In general, the observed decrease testifies to the effectiveness of measures taken to reduce the impact of oil production enterprises, which consist in creating an observation network for monitoring the state of groundwater and eliminating obsolete oil wells. However, in view of the periodic occurrence of accidental spills and leaks of oil products, leading to the preservation of their increased concentration, it is obvious that the measures taken are not enough.

In addition, as the main criterion for assessing the ecological state of groundwater in Kokzhide, an assessment of the average intensity of pollution by oil products was chosen, which is calculated by the formula [18]:

$$\bar{C} = \frac{C_1 + C_2 + C_n}{n} \text{ (mg / dm}^3\text{)},$$

where

$\bar{C}$ – average intensity of pollution with oil products;

$\bar{C}_n$ – concentration of oil products in the sample taken at site n ;

n – is the number of sampling sites (observation wells).

According to the results of laboratory analyzes of groundwater samples taken from 17 wells, the average intensity of oil pollution is 0.28 mg / dm³.

Thus, the value of the average intensity of groundwater pollution in Kokzhide with oil products exceeds the MPC by 2.8 times.

In addition, one of the important criteria for assessing the ecological state of groundwater is the degree of natural protection of groundwater, due to the action of a complex of hydrogeological and lithological factors.

The degree of protection of groundwater can be assessed qualitatively and quantitatively. In a qualitative assessment, only environmental factors are affected, in a quantitative assessment, natural and man-made ones.

The qualitative assessment methodology is based on determining the sum of conditional points and assessing the time to reach the filterable components of the aquifer. These calculations are made without taking into account the nature of moisture transfer and the interaction of pollutants with rocks and groundwater [19].

For an objective assessment of the degree of natural security, the method developed by V.M. Goldberg was chosen. According to this technique, the following are used as criteria for assessing the protection of groundwater: the level of occurrence of groundwater (the thickness of the aeration zone), as well as the thickness, lithological composition and filtration characteristics of poorly permeable rocks of the aeration zone.

Each of these factors is assessed by a special point system. According to lithology, 3 groups of rocks are distinguished, the thickness of which is estimated on a six-point scale (Tables 3, 5). The magnitude of the aeration zone power is assessed on a five-point scale (Table 4). The integral coefficient of groundwater protection is calculated by summing all points. According to the sum of points, 6 categories of groundwater protection are distinguished (Table 6).

Table 3

Lithology and filtration properties of poorly permeable rocks

Group	Deposits	Filtration coefficient
a	Sandy loam, light loam	0,1-0,01 m/day
b	Loams, sandy clays	0,01-0,001 m/day
c	Heavy loams, clays	Менее 0,001 m/day

Table 4

Aeration zone power

<i>H, m</i>	Points
<10	1
10-20	2
20-30	3
30-40	4
>40	5

Table 5

Thickness of low-permeable deposits (m0) and their lithology

<i>m₀, m</i>	Lithology	Points
2	a	1
	b	1
	c	2
2-4	a	2
	b	3
	c	4
4-6	a	3
	b	4
	c	6

Table 6

Groundwater protection categories

<i>Category of protection</i>	<i>Points total</i>
<i>I - very insecure</i>	<i><5</i>
<i>II - unprotected</i>	<i>5-10</i>
<i>III - weakly protected</i>	<i>10-15</i>
<i>IV - relatively protected</i>	<i>15-20</i>
<i>V - protected</i>	<i>20-25</i>
<i>VI - well protected</i>	<i>>25</i>

The groundwater level of the Kokzhide of the first aquifer from the surface is on average 4.6 m, which corresponds to 1 point.

The aeration zone is composed of 3 types of deposits:

- group a - pale yellow fine-grained dry sand (1.5 m) - 1 point;
- group b - yellow uneven-grained clay sand (2.5 m) - 3 points;
- group c - light gray viscous clays (0.6 m) - 2 points.

Consequently, the integral coefficient of groundwater protection is 7 points, which corresponds to the II category of protection related to groundwater unprotected from surface pollution.

Thus, the method of integral assessment of the ecological state of groundwater, consisting of an analysis of the chemical composition, dynamics of distribution and the nature of migration of pollutants in the hydrogeological environment and an assessment of the natural protection of groundwater, is quite effective and informative, since it allows to reveal the most complete picture of the ecological state of groundwater, under conditions of anthropogenic impact.

In general, the analysis of the results of the studies carried out testifies to the extreme ecological vulnerability of underground waters of the Kokzhide, subjected to intensive technogenic impact from the side of oil-producing enterprises. The state of groundwater can be assessed as moderately polluted.

According to the main physical and chemical background indicators, the quality of groundwater meets the requirements for the quality of drinking water. However, widespread excesses of the permissible concentrations of the following components were recorded: oil products, phenols, and total iron. The last one is mainly due to the natural lithological properties of hydrogeological environment and can be eliminated by deferrization during water intake. The increased content of phenols is associated with the high content of petroleum products in the composition of groundwater.

The sources of oil pollution are oil-producing enterprises, the contract territories of which are located on the territory of the Kokzhide groundwater field. At the same time, the greatest excess of the MPC for petroleum products was found in the northwestern part of the field, in the zone of the largest accumulation of oil production wells, which form an increased technogenic load.

In addition, the specificity of the distribution of oil products in the hydrogeological environment of underground waters of Kokzhide is characterized by an increase in the content of oil products with increasing depth, which indicates the presence of damage to the tightness of the cement ring and the establishment of corrosion processes in the casing strings of oil wells.

In addition, the accidental spills of oil products on the surface of the soil revealed during the route surveys in conditions of extremely low natural protection of groundwater from surface pollution contribute to the intensive spread of oil pollution throughout the hydrogeological section.

Thus, this situation requires the immediate elimination of sources of oil pollution of groundwater, which is a strategic reserve of drinking water, the volume of which, estimated at 196.5 thousand m³ / day as of 1983, is adequate to meet the economic and drinking needs of the entire region [5].

Conclusion

The results of this work, as well as a detailed analysis of data on the problem under study, indicate the weak development of hydrogeological aspects of groundwater protection in our country and the need to organize specialized events aimed at restoring the quality of groundwater in Kokzhide.

In particular, the primary task is the comprehensive remediation of groundwater from oil pollution and the remediation of contaminated soil. It is also necessary to identify foci of oil pollution of groundwater and compilation of a large-scale map of contract territories of oil-producing enterprises with the application of all oil wells and an indication of their type.

In view of the facts of accidental spills on the surface of the soil cover, it is necessary to increase the level of control over the production activities of oil producing enterprises by improving the program of industrial environmental monitoring. In addition, in order to obtain a complete picture of the mechanism of the spread of oil pollution and the nature of their influence on the ecosystem of the studied region, it is important to include the following measures in the monitoring research program:

- 1) identification of emergency leaks with subsequent well workover and elimination of obsolete installations;
- 2) reassessment of groundwater reserves with the definition of boundaries and contours of their occurrence;
- 3) expanding the scope of accreditation and the list of analyzed indicators: periodic bacteriological analysis to identify the nature of the impact of oil pollution on the vital activity of aboriginal microflora, as well as radiological analysis of radioactive elements contained in oil;
- 4) carrying out seismic surveys in order to obtain a complete picture of the hydrogeological structure and structure of aquifers, affecting the nature of the spread of pollution (location of hydrogeological windows, the presence of corridors in aquifers);
- 5) determination of filtration properties of rocks of aquifers and construction of a filtration coefficient map;
- 6) study of the nature of migration of pollutants, taking into account the physicochemical processes of interaction of these substances with the components of the hydrogeological environment, as well as the natural processes of self-purification of underground waters in Kokzhide.

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