Comprehensive Environmental Assessment of Territory Influenced by the Karachaganak Oil and Gas Condensate Field in West Kazakhstan Region

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Abstract. The results of the study of soil and natural surface water quality, neighboring the Karachaganak field territory of the West Kazakhstan region are available. The results of three years' air monitoring at the Karachaganak oil and gas condensate field area have been analyzed. The data on the distribution of major pollutants - carbon monoxide (II), nitrogen oxides (IV), sulfur oxide (IV), hydrogen sulfide - in the air of three communities over the years and year seasons are available. The state of the environment in the area of oil and gas industry's activity has been assessed.

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1. Introduction

The problem of assessing the impact of oil and gas field in the state of ecosystems is widely developed at the international level in various oil and gas producing regions. Comprehensive assessment of the ecological state of oil and gas fields is described in the works of Gossen L. P., Velichkina L. M., Ejechi E. O., Ejechi B. O. and others[1-9].

The largest oil and gas project on the development of a unique Karachaganak oil and gas condensate field (KOGCF) with huge reserves of hydrocarbons, located in the West Kazakhstan (WK) causes a number of risks in performing some operations related to the region territory [10,11].

Undustrial projects of oil and gas producing complex are the powerful source of negative effect on various components of natural systems. Continuous exploitation of minefields leads to significant changes in natural water ecosystems and soil cover, in consequence of which it leads to formation of technogenic fluid power systems and soils [2,9].

Among the ecological problems of soil, the primary problem is the pollution by heavy metals, radionuclide and oil&gas emissions. Assessment of ecological state of soil considers soil manageability its biological functions, its designated purpose. The most important problem for North Prikaspy is the saving and soil enrichment during the development of oil&gas fields [8].

At present, many industries use technological cycles, related to discharge in the air of particulate matters and waste gases, chemical composition and concentration of which are defined by production peculiarities [12]. Hydrocarbon production increase at KOGCF is accompanied by the growth of pollutants emission in the atmosphere, what causes serious changes in environment. This all require a systematic control of the ecological situation in this region [13].

Therefore, a timely and continuous environmental compartments monitoring over the area adjacent to the producing fields, always will be one of the most vital tasks for Kazakhstan.

2. Materials and methods.

The research was conducted in 2009-2011 in Berezovsky, Uspenovsky and Zharsuatsky rural districts of Burlin district of WK. Key areas were identified where the surface water and air sampling were carried out; soil profiles setting up and sampling for soil analysis have been made. Localization of sampling places was carried out using GPS system with 12-channel GPS-receiver (Garmin eTrex model). Key area N1 is near Zharsuat village (coordinates as per GPS are - 51°25, 474' NL; 052°47, 042' EL). Key area N2 - near Uspenovka village (coordinates as per GPS - 51°16, 563' NL; 053°35, 620' EL); and key area N3 - near Berezovka village (coordinates as per GPS are - 51° 14, 373 ' NL; 053°20', 763' EL).

Laboratory chemical analyzes were carried out at the Research Institute accredited test center of the West-Kazakhstan Agrarian Technical University named after Zhangir Khan (WKATU).

Methods of atmospheric analysis.

Atmospheric analysis was performed as per the reduced program (route sites). The following parameters have been monitored: H2S, SO2, NO2, CO. The content of pollutants are recorded three times a year: in winter, in spring-summer period and late fall. In the atmospheric analysis, (by year and season) the data of the Research Institute (Accredited Test Center) of the WKATU were used, where the determination of pollutants' content was performed using the accepted instruments - gas analyzer GANK-4 with built-in sensors and chemical cartridges.

Water analysis methods.

Biochemical studies were carried out by chemical (titrimetric, gravimetric) and physico-chemical methods (photo-electro-colorimetric, electrochemical, atomic absorption, fluorescent) in accordance with the GOST requirements. The results were compared with the GOST 17.1.2.04-77 standards "Condition Indicators and Taxation Rules of Fishery Water Bodies" and with the SanPiN 3.01.070-98 "Protection of surface water from pollution".

Sampling for hydrochemical and toxicological water analysis was done in accordance with GOST 2874-73 using the PE-1105 sampler from the surface and the depth of water bodies. Assay reagents match the marks "chemically pure" and "analytically pure." Measurement of pH, chloride-ions was performed on EV-74 universal ionomer instrument according to GOST 26449.1-85; dry residue was determined in accordance with GOST 18164-72: "Method for the determination of non-volatile content". This standard establishes a method for determining the content of dry residue; the concentration of ammonium-ions, nitrate and nitrite-ions was determined by the photocolorimetric method using KFK-2 instrument. Heavy metal content is determined in accordance with the appropriate methods (MVI 001-87-99), by atomic absorption spectroscopy method using the «Varian» device. Determination of oil products was carried by "Fluorat-02-3M" fluorometric analyzer of liquid according to PNDF 14.1:2:4.128-98.

Soil analysis methods.

Sampling was carried out in accordance with GOST 28168-89. Humus content was investigated in accordance with GOST 26213-9, "Determination of organic matter by method of Turin in the modification of CRIASA (ЦИНАО). General characteristics of the soil is identified according to sample analysis with the disturbed and undisturbed structure, selected from soil profiles; oil products - PNDF 16.1:2.21-98, "Method for measuring the mass fraction of oil products in soil and soil base samples by fluorimetric method using liquid analyzer "Fluorat -02"; Analysis for heavy metal content in soil in the research area was conducted in accordance with the Methodology Instructions for the determining heavy metals in soils and crop production. Moscow in 1989, State Standard 2.1.7.020-94.

3. Main part.

Ecological evaluation of air condition.

In Table 1 there are research results of the pollutants' level in the air in key areas of different seasons during 2009-2011. Berezovka village is 1, 72 km southward of the outer fringes of Sanitary Protection Zone of KOGCF. It is the closest community to the oil field. The analysis data in Table 1 show that annually and in all periods of the year the highest concentrations in the atmosphere are the concentrations of carbon monoxide (II)-CO. However these values do not exceed the allowable concentrations that are 5 mg/dm3 for CO. Increase of nitrogen and sulfur oxides content, as well as of hydrogen sulfide is not observed, however, the maximum allowable concentration for these indicators is very low.

Table 1. The content of pollutants in ambient air at the key areas

Place for the sampling	Period	Years / indexes											
		2009				2010				2011			
		NO_2	SO_2	CO	H_2S	NO_2	SO_2	CO	H_2S	NO_2	SO_2	CO	H_2S
Berezovkasai	Winter	0.040	0.035	2.5	0.002	0.045	0.040	2.5	0.002	0.042	0.039	2.1	0.001
	Spring-Summer	0.043	0.039	2.6	0.002	0.048	0.051	2.8	0.003	0.060	0.045	2.3	0.003
	Autumn	0.041	0.031	2.3	0.002	0.043	0.046	2.7	0.003	0.057	0.040	2.1	0.002
Uspenovka	Winter	0.038	0.027	2.5	0.002	0.031	0.030	1.9	Not identif.	0.029	0.028	0.80	0.001
	Spring-Summer	0.031	Not identif.	2.0	0.001	0.038	0.037	2.3	0.001	0.035	0.003	0.90	0.002
	Autumn	0.033	0.018	2.0	0.002	0.034	0.022	2.1	0.001	0.029	0.015	0.87	0.001
Zharsuat	Winter	0.036	0.025	2.4	0.002	0.022	0.017	1.9	0.001	0.020	0.021	1.5	Not identif.
	Spring-Summer	0.020	Not identif.	1.8	0.001	0.029	0.024	2.0	0.002	0.025	0.030	1.7	0.001
	Autumn	0.026	0.011	2.1	0.001	0.018	0.016	1.8	0.001	0.015	0.022	1.6	0.001
	MAC, mg/m^3	0.085	0.5	5.0	0.008	0.085	0.5	5.0	0.008	0.085	0.5	5.0	0.008

Uspenovka village is located on the North-East side and at a distance of 9 km from the field. Table 1 shows that the level of pollutants in the air over this village is rather low in comparison with those in Berezovka village. However, here is also the content of arbon monoxide (II) in the air – on the highest level. There is also no exceedance of Maximum Allowable Concentration (MAC) is observed for any of the indicators.

Zharsuat village is located on the north side at a distance of 9 km from the oil field. The data in Table 1 suggest that the numerical values of air pollutants concentration over Zharsuat village do not different much from those of Uspenovka village. Regularities of a high content of carbon monoxide in the air are also observed in this case. Concentrations of other substances are small enough in comparison

with CO. Comparison with the MAC also shows that the content of all the pollutants in the atmosphere is at the satisfactory level.

Comparison of the data presented in Table 1 shows that the concentration of almost all pollutants in the atmosphere of Berezovka village is higher than in Uspenovka and Zharsuat villages. The level of nitrogen oxide (II) is the most high in Berezovka village, and the lowest – in Zharsuat village. However, in this case, Berezovka village – is the nearest community to the oil field and thus the indexes of air pollution are higher here. Having analysed the seasonal air pollution, it is obvious, that the greatest concentrations of pollutants are in spring-summer period. As per the meteostation data in Aksai, the South wind dominates from September to April, which goes from Berezovka towards the oil field. In summer the dominant winds are the northern and northwest winds. Therefore, the maximum impact of harmful air emissions to the settlement is in summer period. The highest content of carbon monoxide is observed in spring - summer time in each year, and its maximum content was in 2010. It can be assumed that such a seasonal increase of pollutants in 2010 was due to the abnormally hot summer.

Other indicators, such as hydrogen sulfide, sulfur oxide and nitrogen oxide are located, approximately, on the same level, and their highest values are also in the summer of 2010. Illustration of these gases in the atmosphere of Berezovka is shown in the scheme.

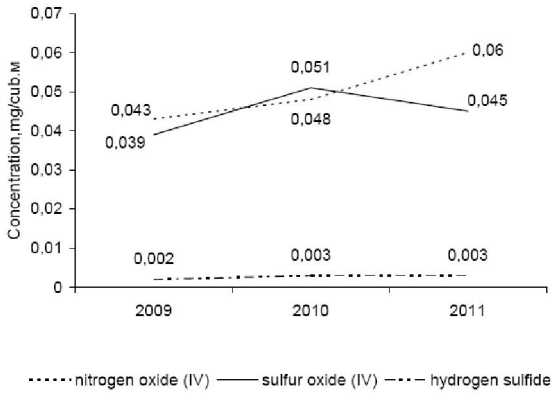

Fig. 1 Distribution of pollutants in the air in spring - summer period in different years in Berezovka village

As it is shown in figure, the nitrogen and sulfur oxides present in the atmosphere in much larger quantities than hydrogen sulfide.

Thus, the research results of atmospheric air in the KOGCF area in 2009-2011 showed the following: the content of carbon monoxide (II) is the abundant in the atmosphere of the studied zone; the highest concentrations of pollutants in all research places and for all the years of research account for spring-summer period; all indicators of air pollutants in the atmosphere of Berezovka are higher than those in Zharsuat and Uspenovka as Berezovka village is the closest to the field; environmental condition of atmospheric air in all areas of research is satisfactory, i.e. no exceeding of MAC was observed.

Environmental assessment of natural surface water.

At the beginning of research, in 2009, a number of standardized hydrochemical characteristics were selected for analysis, including such as the content of suspended material, biochemical oxygen demand, and sulfate ions. The values of the above mentioned figures do not exceed health standards, except for the value of the biochemical oxygen demand (BOD_5). This is an indicator of water quality, which characterizes the total content of organic substances in water after five days of incubation at a constant temperature. Exceedence of this value indicates an excessive amount of organic matter in the test water. Nitrogen ions appear in water mainly as the result of urea and proteins decomposition, which fall into water with the domestic wastewater. The existence, quantity and ratio of nitrogen compounds in the water characterize the degree and duration of water contamination by human wastes. According to the content of these ions the studied water can be used in household purposes, but it is not suitable for drinking.

In subsequent years of research the permanganate oxidability was used as the characteristics of the content of organic matters, and as an indicator of the salt content the size of dry residue was analyzed. In 2010, the spring and summer water samples of Berezovka river was characterized by relatively high salt content and chloride ions concentration, though the MAC was not exceeded. The content of organic and nitrogen-containing substances is also high and is close to the MAC for ammonium ions and permanganate oxidability, especially in spring-summer time. This tendency has continued in 2011 as well, however, the absolute values of hydrochemical indexes, in general are lower than in 2010. Such studies were conducted on natural waters of Ural and Utva rivers near Zharsuat village and near KOGCF. These data show a higher content of organic substance and nitrogen ions, and also suspended particles. The same results were obtained also for the Ural River water in this period near Zharsuat village, where the content of ammonium nitrate and suspended particles also was high. The values of biochemical oxygen demand in

that period in both rivers exceeded the MAC both for the household water and for drinking water. In 2010, the results of analysis again showed a high content of ammonium ions, especially in spring and summer, when the MAC exceedence was 2.25 times higher for the household water. Chloride ions, dry residue, and organic substance also have high indexes. In 2011, the content of nitrogen ions was lower in comparison with 2010, but remained at a high level, especially in spring and summer. Thus, the content of nitrite ions and ammonium ions exceeds the MAC for drinking water. The content of organic matter and of dry residue is still high, though it does not exceed the established norms.

Thus, the analysis of hydrochemical characteristics of the surface water in natural reservoirs in KOGCF zone showed that there is the organic substances and nitrogen ions pollution. A significant part of nitrogen-containing organic compounds get in natural water during the the die away process of organisms, mostly of phytoplankton, and their cells decomposition. The concentration of these compounds is determined by the biomass of aquatic organisms and the rate of these processes. Another important source of nitrogen-containing organic compounds is their lifetime secreting by the aquatic organisms. Among the major sources of nitrogen compounds there are also atmosphere precipitation, where the concentration of nitrogen-containing organic compounds is close to those observed in surface waters. A significant increase of concentration of these compounds is often due to the industrial, agricultural and domestic waste water in water bodies.

Along with determining the hydrochemical parameters of the studied reservoirs the toxicological indicators were investigated, such as heavy metals and petroleum products. In 2009-2011 the water of Ural, Utva and Berezovka rivers was analyzed near to KOGCF for the content of heavy metals ions of zinc, lead (II), cadmium (II) and copper (II), and also of the petroleum products. The analysis showed that in 2009, in all the studied rivers the concentrations of toxic contaminants was within the norms established for surface waters. However, the concentration of lead in the Ural and Utva rivers exceeded the standards established for fishery waters. The content of cadmium in the Berezovka and Utva rivers was also high in terms of the fishery waters rules. Also the copper content in all examined rivers was high. The oil products content was also high, but within the norms. In 2010, the highest concentrations of toxic contaminants in all the studied water reservoirs have occured in spring and summer time. In 2011, the work on the determination of toxic pollutions in Berezovka and Utva rivers and in Uspenovka pond has continued (Table 2).

The data in Table 2 again suggests the presence of heavy metals pollution in the studied natural surface water. Pollutions are more evident during the summer time. The lead and cadmium pollution - are the highest. Zinc pollutions are seasonal. In general we can conclude that in all the investigated surface waters there are heavy metal polloutions, particularly lead, cadmium and copper pollutions. These contaminations are more evident in spring and summer. Significant pollution changes over the years were not observed.

Table 2. Results of chemical analysis of heavy metals and oil products in surface waters near the KOGCF in 2011. (* for surface waters; ** for waters of the commercial fishing importance)

Place of sample collection	Time of sample collection	Controlled parameters, mg/dm^3				
		Zn	Pb	Cd	Cu	Oil products
Utva r. (near to Zharsnat)	May	0.0120	0.0510	0.0132	0.0112	0.012
	June	0.0440	0.0800	0.0150	0.0130	0.028
	September	0.0006	0.0050	0.0130	0.0095	0.025
Uspenovka pond (near to Uspenovka)	May	0.0225	0.0311	0.0050	0.0240	0.002
	July	0.0350	0.1500	0.0180	0.0340	0.023
	September	0.0021	0.0030	0.0010	0.0048	0.007
Water reservoir on Beryozovka r. (near to Berezovka)	May	0.0240	0.0911	0.0101	0.0092	0.021
	July	0.0470	0.1400	0.0280	0.0160	0.026
	September	0.0087	0.0001	0.0230	0.0035	0.008
MAC, mg/dm^3, not more		*1.0	0.03	0.001	1.0	0.3
		**0.01	0.1	0.005	0.005	0.05

Environmental assessment of soil condition. Evaluation of soil condition near to KOGCF area showed the following: at depth of the arable layer the measured parameters varied depending on the observation place and depth of soil sampling - acidity (pH) within 7.6-7.8; humus - 2.8-3.2%; hydrolyzable nitrogen (N) - 150-215 mg/kg; P_2O_5 – 8.0-13.0 mg/kg; K_2O - 330-450 mg/kg. Research results of the chemical components in soil determined that the ecological condition of soil fertility is satisfactory and there are no rapid changes in the concentration of chemical components. Laboratory analysis results of soil samples in 2010 in the KOGCF area detected that the concentration of oil products was within 0.017-0.028 g/kg, which is significantly below the prescribed sanitary standards.

Heavy metals (HM) belong to the priority-oriented pollutants, which must be monitored in all environments. Soil is one of the main concentrators of HM in biosphere. Heavy metals usually concentrate in near-surface soil 0-10 (20) cm, where they are present in the form of exchangeable ions and in nonexchangeable form, which is firmly fixed by soil absorption complex. The heavy metal concentration is presented in Table 3.

Table 3. Heavy metal concentration in soil near to KOGCF

N	Place of sample collection	Sampling depth, cm	Controlled substances, mg/kg			
			Pb	Zn	Cu	Cd
1	Uspenovka v.	0 – 20	6.078	21.733	7.003	0.431
		20 – 40	5.130	17.213	7.053	0.011
2	Berezovka v.	0 – 20	6.754	19.004	8.375	0.521
		20 – 40	5.007	19.751	9.005	0.221
3	Zharsuat v.	0 – 20	4.357	21.504	8.124	0.372
		20 – 40	4.001	20.296	8.956	0.023
		MAC, mg/kg, not more	6.0	23.0	3.0	0.5

Accumulation of heavy metals in soil destroys the physicochemical balance of natural system and provokes a number of processes, which influence on soil properties. The pH starts to change, the soil absorption complex begins to destroy, microbiological processes starts to break. As the result of soil structure breaking the water-air regime deteriorates, soil humus degrades, and eventually the soil loses its fertility.

In soils, adjacent to Uspenovka village a nonsignificant exceedence of mobile lead was detected. Among the areas examined, a noticeable excess of mobile lead was detected in the soil near Berezovka village and KOGCF. Perhaps it is due to the close proximity of road and more complete traffic. Increase in the lead concentration in soils was observed mainly at a depth of 0-20 cm. In sois of the other studied areas the concentration of lead was below the MAC.

In all examined areas near to KOGCF the mobile zinc concentrations varied within 15.481-25.502 mg/kg, and its content was lower than MAC (23.0 mg/kg). The mobile copper exceedence as per MAC (3.0 mg/kg) was observed in all the examined soils. Cadmium concentration in soil samples was within the MAC (0.5 mg/kg), except the Berezovka soil, from the depth of 0-20cm. Thus, as per the results of soil chemical analysis, there had been detected a high concentration of heavy metals, especially copper, which exceeded the MAC by 4.1 times. So far, it can be assumed that the high concentration of heavy metals corresponds to the natural geochemical background of the West Kazakhstan region.

4. Conclusion

The carried out comprehensive environmental assessment the KOGCF territory revealed a certain impact on the environment of the territories during the studied period, but not exceeding the standard ratios. Considering the intensity of the field development, it is recommended to conduct a systematic comprehensive examination in order to effectively monitor and timely take decisions to prevent the deterioration of the environment and the living conditions of local people. Our research has established a framework for setting up a network of environmental monitoring for the environmental compartments in the zones of oil and gas production's influence. We have created an observation system which will allow objectively evaluate and forecast the peculiarities of natural environments' interaction with engineering structures in the conditions of oil and gas resources development.

The obtained results of systematic environmental studies allow giving an objective mark to the environmental situation in areas of high technogenic burden and can be used in other regions with similar oil and gas fields.

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