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# Complex ecological monitoring of negative impact of oil-containing waste in areas of oil fields as an object of ecological risk

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In this paper peculiarities of negative impact of oil-containing waste to humans and biosphere and approaches to its estimation are considered. For the estimation of ecological risks of negative impact of oil-containing waste in areas of oil and gas fields it is suggested to take into account not only its toxicological and quantitative characteristics, but also the degradation of the territories of fields, potential recultivating capacity of fields, suitability of wastes for utilization etc. Negative ecological impact not only from operation but also from mothballed oil well should be investigated. Results of complex experimental researches of negative impact of oil-containing waste in regions of development and exploitation of oil and gas fields are described. In number of cases increased values of oil containing waste and heavy metals were determined in soil and in water environment. For oil wells of Mogutovskoye field acute toxicity of soil samples near to the wells and excess over maximum permissible concentrations of methane were determined. Results of monitoring of toxicological impact of oil containing waste in areas of different oil fields of Samara region and in oil treatment plants by using of biological testing methods have showed that a number of samples have enlarged toxicity and are causing acute toxic effect to the test-organisms – green algae *Chlorella vulgaris* Beijer and *Scenedesmus quadricauda* (Turpin) Brébisson, crustaceans *Daphnia magna* Straus. In number of cases increased values of oil products was observed. Thus, it was determined that negative impact of oil-containing waste in areas of oil fields is complex in nature and may cause significant ecological risks for air, water and soil. Results of work allow us to carry out more efficient and high quality monitoring of negative impact of oil-containing waste and estimation of ecological risks as well as to develop the measures for reduction of negative impact of oil-containing waste.

***Keywords:*** oil-containing waste, negative impact, oil fields, ecological monitoring, estimation, ecological risk.

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# Комплексный экологический мониторинг негативного воздействия нефтесодержащих отходов в районах нефтяных месторождений как объекта экологического риска

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В работе рассматриваются проблемы негативного воздействия нефтесодержащих отходов на человека и биосферу и подходы к его оценке. Для оценки экологических рисков негативного воздействия нефтесодержащих отходов в районах нефтегазовых месторождений предложено учитывать не только их токсикологические и количественные характеристики, но также деградацию территорий месторождений, потенциальную рекультивационную способность месторождений, пригодность отходов к утилизации и др. Следует исследовать негативное экологическое воздействие не только от действующих, но и от законсервированных нефтяных скважин. Описаны результаты комплексных экспериментальных исследований негативного воздействия нефтесодержащих отходов в районах разработки и эксплуатации нефтегазовых месторождений. В ряде случаев установлено повышенное содержание нефтепродуктов и тяжёлых металлов в почве и водной среде. Для нефтяных скважин Могутовского месторождения установлены острая токсичность проб почвы вблизи скважин, а также превышение предельно допустимых концентраций по метану. Результаты мониторинга токсикологического воздействия нефтесодержащих отходов в районах различных месторождений Самарской области, а также на нефтеперерабатывающих предприятиях, с использованием методов

биотестирования показали, что ряд проб обладают повышенной токсичностью и оказывают острое токсическое действие на тест-организмы: зелёные водоросли *Chlorella vulgaris* Beijer и *Scenedesmus quadricauda* (Turpin) Brébisson, рачков *Daphnia magna* Straus. Таким образом, установлено, что негативное воздействие нефтесодержащих отходов в районах нефтяных месторождений носит комплексный характер и может создавать значительные экологические риски как для воздушной и водной сред, так и для почвы. Результаты работы позволяют осуществлять более эффективный и качественный мониторинг негативного воздействия нефтесодержащих отходов и оценку возникающих при этом экологических рисков, разрабатывать мероприятия по снижению негативного воздействия.

***Ключевые слова:*** нефтесодержащие отходы, негативное воздействие, нефтяные месторождения, экологический мониторинг, оценка, экологический риск.

Negative impact of oil containing waste is a serious problem due to the fact that they have a complex negative impact on the soil, air and water medium and pose a great danger as for the humans as for the biosphere in total [1–6].

The main types of oily wastes are oil sludges and drilling wastes formed in the process of oil production, oil emulsions, waste from oil containing wastewater treatment plants, oil sludges from stripping tanks and equipment, formed in the process of oil refinement. Additional ones include the wastes collecting in result of oil spills, e.g. sorbents contaminated with petroleum products. During the development and exploitation of oil and gas fields the oil containing wastes are causing the complex negative impact, including toxicological, radiation, chemical etc.

For the development of the effective methods and solutions to reduce negative impact of oil containing wastes to the biosphere it is necessary to carry out ecological monitoring. Efficient ecological monitoring allows us to ensure the sanitary-epidemiological and ecological well-being of the population in urban territories, to take timely and qualitative measures to reduce the negative impact of pollutions to the biosphere [1, 2, 5]. Results of ecological monitoring allow us not only to get real values of substances, but also to determine the ratio between a certain concentration of a substance which is polluting the environment, and the likelihood of a negative impact on human health, to estimate ecological risks of negative impact to the biosphere.

Analysis of existing methods of ecological monitoring of oil containing wastes to the biosphere is showing that due to the high cost and technological complexity the use of a number of them is limited. They have a number of disadvantages and they cannot provide a complete and qualitative assessment of pollution parameters generated by the oil containing wastes. The methods of ecological monitoring traditionally used at the present time are often not allowing us to determine precisely the degree of ecological danger from the impact of oil containing waste. These methods do not reflect the level of anthropogenic impact on the population and biogeocenoses, they do not show the reactions of living organisms to this effect, they do not take into account the combined effect of the factors of different nature (physical, chemical, biological) on a person.

The actual task is improving methods and approaches to environmental monitoring of impact of oil containing wastes to biosphere as a source of ecological risk and obtaining new experimental data.

The purpose of the work – to carry out comprehensive environmental monitoring of negative impact of oil containing wastes in areas of development of oil fields and to get new experimental data.

## Materials and methods of research

Selection of the methods of ecological monitoring during the impact of oil containing waste and oil products to biosphere should be made taking into account available sources of pollutions and the kinds of pollutions: chemical, biochemical, microbiological, etc. [2, 6–8]. It should be taken into consideration that for estimation of the state of the objects of biosphere in changing environmental conditions not only quantitative characteristics of pollutions, but also their consequences are becoming important. Minimizing of the cost of technical means it should also be taken into account [1].

Oil containing waste may have high degree of toxicity [3, 4, 8]. One of efficient approaches for the determination of the degree of toxicity of the soil and water objects polluted by the oil containing wastes and by the oil products is using of the methods of biological indication and of biological testing [9–13], giving us an objective integral estimation of the quality of environment and grounds for forecasting the state of ecosystems.

Complex approach in carrying out environmental monitoring of oil containing wastes (combination of methods of biological

indication and of biological testing, methods of quantitative chemical analysis, radiation control etc.) with systematic observation is allowing us to judge not only the quantitative characteristics of pollutions, but also about perspectives of community structure changes, productivity of populations and about the sustainability of ecosystems.

The approach proposed by the author assumes that at the preliminary stage of monitoring it is reasonable to develop a conceptual model of the territory, representing a graphical or descriptive representation of possible relationships between the oil containing waste as sources of environmental pollution and routes of exposure. Then it is necessary to carry out calculating and instrumental evaluation of the parameters of oil-containing waste in the analyzing objects of environment, and also to use the data of previous monitoring researches. It should be noted that for the estimation of negative impact of oil containing wastes it is necessary to carry out researches not only of the waste itself but also the land areas and water objects near to the places of development of oil and gas fields, oil containing wells etc. In particular, the analysis of soil ground samples, bottom sediments, radiation control, measurements of parameters of air environment etc. it should be carried out.

For the estimation of ecological risks of negative impact of oil containing wastes in areas of oil and gas fields it is suggested to take into consideration not only its toxicological and qualitative characteristics, but also degradation of the territory of fields, potential recultivating capacity of oil fields, the ability of waste to phase-disperses concentration, suitability of waste for utilization etc. Negative environmental impacts should be investigated not only from operating oil wells but also from mothballed ones.

When conducting quantitative chemical analysis of oil containing waste on the presence of oil products it is reasonable to use federal environmental regulation (PND F 16.1:2.21-98), for heavy metals – federal environmental regulations (PND F 16.1.40-03 – cadmium, cuprum, lead, zink), FR.1.31.2010.07281 (nickel), federal environmental regulation (PND F 16.1:2.3:2.2:3.57-08 – aluminum). When determining the percentage of components of oil containing wastes it is necessary to determine oil products (federal environmental regulation (PND F 16.1.2:2.2:2.3.3.64-10), humidity (Russian Sate Standard 2477-2014, federal environmental regulation PND F 16.2.2:2.3:3.27-02), ash content (federal environmental regulation PND F 16.2.2:2.3:3.29-02), the hydrogen index (federal environmental regulation PND F 16.2.2:2.3:3.27-02).

During the estimation of toxic impact of oil containing wastes in soil and in water objects it is reasonable to use green algae *Chlorella vulgaris* Beijer and *Scenedesmus quadricauda* (Turpin) Brébisson, crustaceans *Daphnia magna* Straus [2, 9, 10, 13] (PND F T 14.1:2:4.12-06, 16.1:2:3:3.9-06, FR.139.2007.03222, FR.139.2007.03223 etc.).

## Results and discussion

Complex experimental researches of the negative impact of oil containing wastes to environment were carried out in areas of development and exploitation of oil and gas fields of Samara and Orenburg regions.

In Sergievsk district of Samara region soil samples were analyzed in the area of production wells of Yakushkinskoye field, taken in the different distances from the wells. For production well No. 1027 it was determined increased content of oil products as well as of the cuprum (gross form) and nickel (gross form) inside the boning.

In Zolnoye oil field complex researches of soil and water at the distance up to 200 meters from the Volga river bank were carried out. In the downstream part during visual and smell inspection no traces of petroleum products were found near the shore and on the towpath, including the location of operation of floating crane carrying out soil sampling at the distance approximately 100 meters from the river shore. In the upstream part oil film contamination detected in the area of booms specially installed in 2012 along the water edge. Samples of water, aquatic vegetation, and the ground were taken in area of garden non-profit partnership 7 of the village of Zolnoye. The scheme of sampling sites is shown in Figure.

Film contamination of oil products with the smell of a light fraction of hydrocarbons and the output of oil products from the bottom were detected on a local area of approximate size 50 m along the coast and 5–10 m from the coast. At the same time as outpourings forming an iridescent film in place as well as small outlets of gas jets with an admixture of oil products were observed. In the area of the spill for a long time there was oil preparation station of Zolnenskoye field liquidated in the 1990s, from which the ducker came out through the Volga River towards the village of Zadelnoye. Presently the territory of the in-

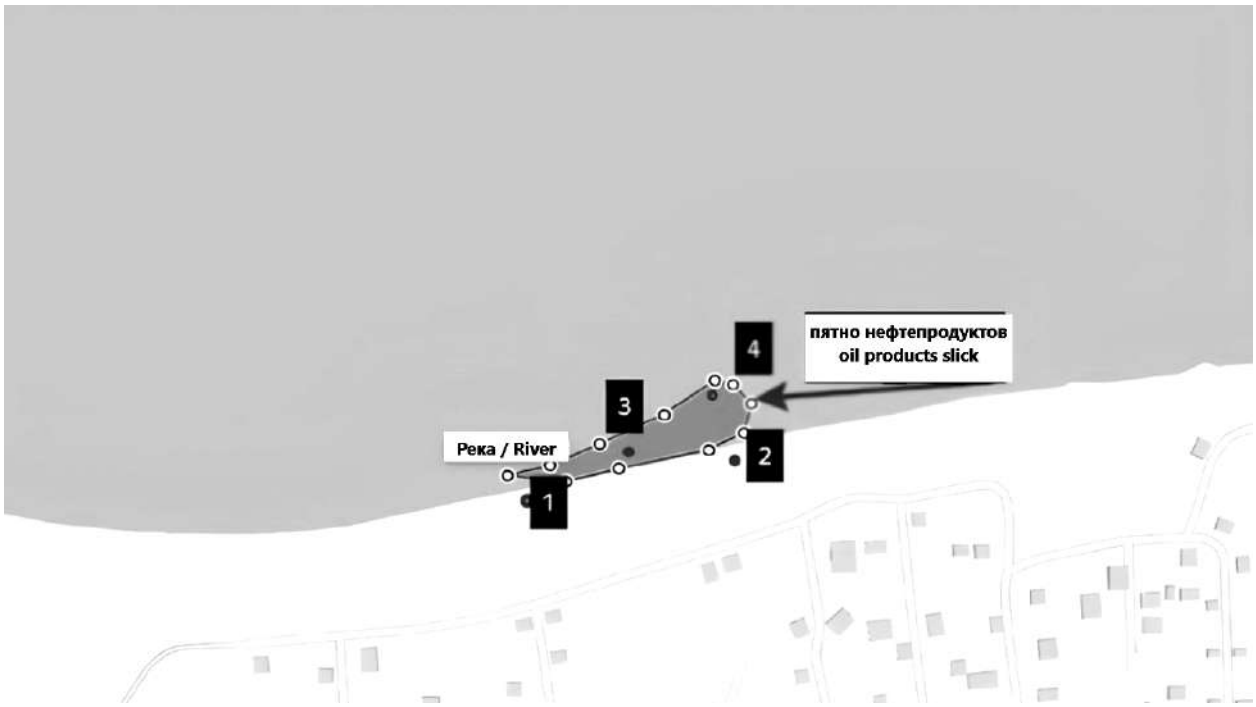


**Fig.** The scheme of sampling sites in area of the village of Zolnoye of Samara region (explanations in the text)

dustrial zone is built up by a garden partnership. At the territory of garden non-profit partnership in the ravine there were previously cases of oil products emission from the soil ground (e.g. in the year of 2012). Water pollution was noted e.g. in the review of Russian Hydro Meteorological Service for May of the year 2022.

Soil samples were taken on the shore from a depth of 0.4 m along the shore at the distance 2–3 m from the water and along the talweg of the ravine in 50 m from the coastline at a height of about 6 m from the water's edge (points 1 and 2 in Figure). In coastal samples a sharp change in the nature of the soil was detected, passing into the black anaerobic zone with the remains of fuel oil on the buried pebbles and a specific smell of changed oil products (presumably oil sludge). The zone of changes starts from a depth of 0.1–0.2 m without going to the surface and submerges below the water level to an unspecified depth. The soil of the towpath is gravel-pebble-gravelly with the unsorted debris. Samples of water and aquatic vegetation were also taken from the surface in the place of the maximum accumulation of the rainbow film.

By thalweg soil was detected of clearly of man-made origin based on artificially displaced loams and heterogeneous fragments of carbonate rocks lying at the different levels. During visual examination at this site of samples selection no impurities of oil products were detected.

Results of laboratory research of ground samples taken in points 1 and 2 according to the scheme of the measurements in fig.1 are shown in Table 1. Significant content of oil products increasing of the sanitary norms values in probe taken in point 1 was determined. During the analysis of the probe taken in point 2, increased content of oil products was also observed.

The samples of bottom sediments (river bottom) near to the bank on the depth 2.7 m (point 3) and on the depth 7.9 m (point 4) were also analyzed. Results of biological testing of soil probes with using of test-objects algae *S. quadricauda* and of crustacean *D. magna* are showing that the studied samples do not have an acute toxic impact. So, for a sample of bottom sediments taken at the depth of 2.7 m (point 3), by algae a change in the fluorescence level (inhibition) 14% was observed (without diluting the water extract), by daphnia – mortality 0% (without diluting the water extract). Thus, acute toxicity for these samples has not been determined. At the same time, an increased content of the oil products was observed for both samples.

Pollutions of soil and of air, radiological characteristics near to oil pipelines and mothballed oil wells in the area of Mogutovskoye field of Orenburg region were also investigated. Results of laboratory research of soil samples in area of the well No. 107 of Mogutovskoye field of Orenburg region are shown in Table 2. Analysis of results of

**Table 1**

Results of laboratory research of soil samples near to the river bank in points 1 and 2 in the village of Zolnoye of Samara region in area of garden non-profit partnership 7

| Name of the component (indicator), unit of measurement | Result of measurement and attributed measurement error (uncertainty) | |
|---|---|---|
| | Point 1 | Point 2 |
| Cadmium (gross form), mg/kg | 1.1±0.4 | 0.83±0.33 |
| Cuprum (gross form), mg/kg | 9.9±3.0 | 6.6±2.0 |
| Lead (gross form), mg/kg | b.d.l. | b.d.l. |
| Zink (gross form), mg/kg | 50±18 | 52±18 |
| Nickel (gross form), mg/kg | 12.1±3.1 | 4.3±1.4 |
| Aluminum (gross form), mg/kg | 0.13±0.05 | 0.47±0.19 |
| Oil products (gross form), mg/kg | 6200±1600 | 300±80 |

*Note to tables 1 and 2: b.d.l. – below detection limit.*

**Table 2**

Results of laboratory researches of soil samples near the well No 107 and at the distance 2.5 m from the well No 107 of Mogutovskoye field of Orenburg region

| Name of the component (indicator), unit of measurement | Result of measurement and attributed measurement error (uncertainty) | |
|---|---|---|
| | soil sample near the well No. 107 | soil sample at the distance 2.5 m from the well No. 107 |
| Cadmium (gross form), mg/kg | 0.75±0.30 | b.d.l. |
| Cuprum (gross form), mg/kg | 10.8±3.2 | 17±5 |
| Lead (gross form), mg/kg | b.d.l. | b.d.l. |
| Zink (gross form), mg/kg | 72±25 | 52±18 |
| Nickel (gross form), mg/kg | b.d.l. | b.d.l. |
| Aluminum (gross form), mg/kg | b.d.l. | b.d.l. |
| Oil products (gross form), mg/kg | 1150±290 | 300±75 |

measurements is showing that near to the well and at the distance 2.5 m from the well there is a significant content of oil products and zink (gross form).

Analyses of samples taken near the well No. 103, and also near to the oil pipeline of the Mogutovskoye field of Orenburg region, are showing the increased content of oil products.

Results of biological testing of soil samples taken near to the wells No. 103 and No. 107 with using of test objects algae *S. quadricauda* and crustacean *D. magna* are showing that the studied samples have an acute toxic effect. For the samples of soil taken near to the well No. 103 by algae a change in the fluorescence level (inhibition) 94% was observed (without diluting the water extract), by daphnia – mortality 100% (without diluting the water extract). For the samples of soil taken near to the well No. 107 by algae a change in the fluorescence level (inhibition) 92% was observed (without diluting the water extract), by daphnia – mortality 100% (without diluting the water extract).

The state of the atmosphere air near to the mothballed wells of the Mogutovskoye oil field was estimating with using of gas analyzer GANK-4 by methane, carbon monoxide, saturated hydrocarbons and hydrogen sulfides content. At the maximum permissible one-time concentration ($MPC_{m.s.}$) of methane (approximately safe level of exposure) in atmosphere air 50 mg/m$^3$ in a number of points of measurements exceeds were observed: in the area of well No. 103 the average concentration of methane was measured equal 88.5 mg/m$^3$, in the area of well No. 107 the average concentration of methane was measured equal 95.9 mg/m$^3$. Thus, almost twice the excess of $MPC_{m.s.}$ of methane was observed. An insignificant exceeding of maximum permissible concentration for hydrogen sulfide was also found near to the well No. 107. According to other parameters of atmospheric air, no exceeding has been determined.

In results of measurements of gamma-radiation and of volume activity of radon in the air near to the oil field and the mothballed wells of the Mogutovskoye oil field no excess of admissible norms was detected.

Results of monitoring of toxicological impact of oil containing wastes in areas of the

different oil fields of Samara region and also in oil treatment plants with using of the methods of biological testing are showing that a number of samples are having the increased toxicity and are causing acute toxic impact on test-objects *C. vulgaris* and *D. magna*. It was determined that a number of investigated samples of soil are having high toxicity and hyper toxicity. For example, the probes of soil taken near the cisterns on one of the objects were causing the hyper toxic impact to the test object *D. magna* in the range of concentrations 0.011%–1% and 0.12%–10%. 100% mortality of test object was observed within a few minutes-hours after the start of the biological testing at any concentration of the range. Also, the studied samples had a hyper toxic effect on *C. vulgaris*. Results of qualitative chemical analysis of samples, including sludges cleaning of tanks and pipelines from the oil and the oil products are also showing that in number of the cases increased content of oil products and of ahs content is observed. Thus, it was determined that oil containing wastes in a number of cases are having acute toxicity and may cause significant negative impact to the human and to the biosphere.

## Conclusion

New approaches to the estimation of negative impact of oil containing wastes to the humans and to the biosphere are suggested. It is necessary to carry out the investigations not only of wastes, but also land territories and water bodies near to the areas of development of oil gas fields, oil-bearing wells etc. In particular, soil samples, bottom sediments should be measured, as well as also radiation control, measurements of parameters of atmosphere air etc. should be carried out. For the estimation of ecological risks of negative impact of oil containing waste in areas of oil and gas fields it is suggested to take into consideration not only its toxicological and qualitative characteristics, but also degradation of the territories of oil fields, potential recultivating capacity of oil fields, the ability of waste to phase-dispersed concentration, suitability of wastes for utilization etc. It is necessary to investigate negative ecological impact not only from operating but also from mothballed oil wells.

Complex experimental researches of negative impact of oil containing wastes in the areas of development and exploitation of oil and gas fields were carries out.

Results of monitoring of toxic impact of oil containing wastes in areas of different oil fields of Samara region, and also in oil refinement enterprises with using of the methods of biological testing are showing that the number of the samples are having increased toxicity and have an acute toxic impact. Results of quantitative chemical analysis of samples, including sludges cleaning of tanks and pipelines from the oil and oil products, are also showing that, in some cases, there is an increased content of oil products and the ash content.

Thus, it was established that negative impact of oil containing wastes in the areas of oil fields it is complex in nature and may cause significant ecological risks as for air and water environment, and for the soil.

Results of this work are allowing us to carry out more efficient and quality monitoring of negative impact of oil containing waste to biosphere and the estimation of emerging ecological risks, to develop the measures to reduce negative impact.

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