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Impact of the oil production complex on land pollution in Russia

Влияние нефтедобывающего комплекса на загрязнение земель в России

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Abstract

The assessment of the impact of the economic activities of the Russian oil-producing complex on land pollution contributes to the adoption of evolutionary management decisions. It also helps to take into account the opinion of society, the Ministry of Emergency Situations. In the oil complex, industrial pollution negatively affects flora and fauna. It's important to identify the level of exposure, the degree of its danger, the location of the contamination. The work deals with the methodology, information-logical and mathematical model of solving the above problem. The main result of the work is a system and procedure (technique) for analyzing the results of monitoring and forecasting of land cover take into consideration the sanitary and hygienic consequences of residual content of petroleum products. As a result of the system analysis, an approach to the construction of alternative solutions has been proposed, taking into account not only permissible pollution standards, but also environmental, sanitary and epidemiological norms and assessment methods. The emergence of soil systems, their categories, is taken into account. In particular, (in importance) risks for soil cover-morphological, bio-physical-chemical, ecological-health, toxic influence and irreversible

Аннотация

Оценка влияния хозяйственной деятельности российского нефтедобывающего комплекса на загрязнение земель способствует принятию эволюционных управленческих решений. Это также помогает учитывать мнение общества, МЧС. В нефтяном комплексе промышленное загрязнение негативно сказывается на флоре и фауне. Важно определить уровень воздействия, степень его опасности, место загрязнения. В работе рассматриваются методология, информационно-логическая и математическая модели решения указанной задачи. Основным результатом работы является система и методика анализа результатов мониторинга и прогнозирования состояния почвенного покрова с учетом санитарно-гигиенических последствий остаточного содержания нефтепродуктов. В результате системного анализа предложен подход к построению альтернативных решений, учитывающий не только допустимые нормы загрязнения, но и экологические, санитарно-эпидемиологические нормы и методы оценки. Учитывается возникновение

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processes and bifurcations, including taking into account regional peculiarities and restoration potential of soil, are considered. Proposed algorithm of simulation and system analysis is based on situational modeling. Evolutionary modeling allows you to adapt the prediction and assessment procedure (methodology) to the risk factors of the environment. It increases accuracy (formalization and evidence) and completeness of conclusions, efficiency of situation analysis, which affects manageability of risk both for oil complex and for individual enterprise of the industry. The results of the work may be used for the development of software tools, in particular expert and predictive systems. Situational models are needed when oil companies are addressing multi-criteria and multi-factor decision-making challenges.

Keywords: modeling, oil complex, pollution, evolutionary, risk, soil, earth, system analyses.

почвенных систем, их категорий. В частности, рассматриваются (по значимости) риски для почвенного покрова-морфологические, биофизико-химические, эколого-гигиенические, токсическое воздействие и необратимые процессы и бифуркации, в том числе с учетом региональных особенностей и восстановительного потенциала почв. Предлагаемый алгоритм моделирования и системного анализа основан на ситуационном моделировании. Эволюционное моделирование позволяет адаптировать процедуру прогнозирования и оценки (методологию) к факторам риска внешней среды. Это повышает точность (формализацию и доказательность) и полноту выводов, эффективность ситуационного анализа, что влияет на управляемость рисками как для нефтяного комплекса, так и для отдельного предприятия отрасли. Результаты работы могут быть использованы для разработки программных средств, в частности экспертных и прогностических систем. Ситуационные модели необходимы, когда нефтяные компании решают многокритериальные и многофакторные задачи принятия решений.

Ключевые слова: моделирование, нефтяной комплекс, загрязнение, эволюция, риск, почва, земля, системный анализ.

Introduction

Oil production and processing are major land pollutants. In Russia such enterprises - about 17% (total world production). Prompt and well-prepared expertise prevents possible unfavorable situations. It takes into account deviations of soil-ecological parameters from permissible residual content of oil products in soil, according to the norms of state documents, for example, (Recommendations, 1995).

Oil production is also a harmful human activity; it impairs the environmental situation around the world, as in Russia. This is due, for example, to the fact that the final product (for example, gasoline) is not more than 5-10% of the produced volume. Raw material waste entering the biosphere, particularly the soil, is toxic, carcinogenic and even mutagenic. They contain substances of both organic and inorganic origin. Wastes generated during drilling include a wide range of organic and inorganic substances. In intensive well operation, various acids, inhibitors, etc., are used. About half (56%) of the waste is water, 28% - washing solutions, and the remaining 16% - removable rock (Barabanshikov, Serdyukova, 2016).

Russian regulations and regulations are considered sufficiently strict (Ivshina, I.B. et al, 2015). They exclude the possibility of oil products entering the medium adjacent to the well or processing plant. At the same time it is allowed to involve land in economic turnover with restrictions of non-environmental regime of use. Providing sanitary and hygienic standards of soil purity in the process of self-healing, without the use of additional special measures for recultivation. Bioclimatic, landscape, soil parameters and structures, categories and types of land, composition of oil products are taken into account (Alekseenko, 2013).

The purpose of our work is a systematic analysis of the emergent properties (Glukhova, Kaziev &

Kazieva, 2018) of soil impact assessment systems taking into account risks and anthropogenic load. The main result of the work is the methodology, procedure of modeling and analysis of the results of prediction of the soil condition taking into account their contamination with oil products. This is necessary to reduce the risks of impact on the region's soil and health (Sinha, et al, 2017).

In the work, we propose to systematically analyze alternative solutions that take into account of only permissible pollution standards (MPC) and to move to differentiated environmental and sanitary-epidemiological standards and methods of assessment taking into account ergicity by soil categories.

Theoretical foundations

The rate of generation of soil, vegetation cover is low, and this important factor of human life cannot be lost. The soil contaminated with hydrocarbons becomes oily, unsuitable for agricultural use. Intensified control of oil soil pollution (Gennadiev, 2015) requires an individual approach, individual measures to prevent, eliminate damage.

Equally important is the systematic analysis of the organization of monitoring and prevention of pollution, efficiency of elimination and restoration measures for the environment. The most comprehensive such measures and programs of reconstruction have been developed in Russia by regions: KhMAO-Ugra, Komi, Chuvashia, Tatarstan, Udmurtia. In other regions not so dependent on oil, they focus on the specific content of oil products and the letter of the Ministry of Natural Resources of the Russian Federation (Letter, 1993), where the "permissible" levels of oil in the soil are given.
Oil refining causes great damage to plant cover. Pollution occurs through leaks, accidents and transportation. The impact of oil production and processing on the environment is also increased by:

1) inadequate industry requirements;
2) inefficient transportation;
3) lack of investments in risk forecasting, prevention of damage;
4) insufficient attention and investment of environmentally optimal production.

In the study, risks to the soil cover are identified by importance:

1) violations of morphological, bio-physical-chemical properties (loss or alienation of land use);
2) inability to perform ecological and health functions as a result of accumulation of hydrocarbons and impurities contained in oil and poorly neutralized in soil (Buzmakov, Yegorov & Gatina, 2017);
3) toxic effect of contaminated sites on humans and microorganisms in soil;
4) irreversible processes and bifurcations (Muzica, 2011) during oil field operation.

According to the standards for soils in order to minimize the spread in the environment, deterioration of agricultural products and sanitary and hygienic environment, appropriate methods and recommendations have been developed, in particular, proposed in the work Shtripling, Kholkin & Larionov, 2016. In particular, 5 levels of soil contamination with petroleum products (in mg/kg) have been identified:

1) permissible (up to 1000; Level in 1 g of oil per 1 kg of soil);
2) low (1000–2000;
3) average (2000–3000);
4) high (3000–5000);
5) very high (from 5000).

These standards do not take into account regional features (background) and recovery potential of soil types (Balandina, et al, 2015). As a result of monitoring, expert procedures and system analysis, it is important to highlight the ergent properties and propose a system procedure based on them. There's need for situational modeling (Germanova, et al 2020).

Methodology

Various methods of soil pollutant purification and neutralization are used. Not all are safe for the environment, many are expensive, energy-intensive or labor-intensive, others are only suitable for high pollution risks, such as oil spills (Quen Thi Quinh An, et al, 2019).

One rational, available with large contamination methods is soil bioremediation (Voinov, 2018). It is based on the natural-metabolic activation of biological objects (microorganisms, plants, etc.) and the use of photosynthesis energy, reactions like catalysis. The latter change the physical and chemical composition and structure of soil and oil products, especially when contaminated with heavy metals. The method does not require bulk earthworks, large investments.

Since in our work one of the important tasks is self-organization, use of self-organization potential, this method is most relevant to this goal. The purification process in this case - initially self-organized is carried out by the forces of bioactive substances in the soil itself. Social Mining models and methods can be used to model such processes (Kaziev, et al, 2019).

We also use methods of analysis and synthesis, decomposition and aggregation, prediction and situational modeling, computational experiment, statistical analysis, classification, etc. Evolutionary modeling is also used, which adapts the system to return to the trajectory, increases its evolutionary capabilities. The method (algorithm) of work of Schwyryaev and Menshikov (2006) was also used.

When predicting contamination, data is not always normally distributed, as are data errors. Therefore, we perform preliminary analysis, for example, as in Fetisov and Kolesnikov (2018).

But we used the simpler following procedure (using a formal language like Pascal):
repeat

{if < there is coarse data >, then consistently find the average, moments, variations, distribution points of the Student (critical - 5%, 0.1%) and solve the task of deleting the data if necessary}
until < do not exhaust the list of values by rank.
The procedure (algorithm) proposed in the work for assessing the degree of soil contamination and land disposal from agricultural turnover provides forecast estimates "on the depth of the process." It uses both balance-sheets, semi-empirical methods and computer modeling and a computational, simulation experiment aimed at a multi-criterion technique of identifying and then localizing oil pollution with subsequent waste disposal. As well as with the assessment of economic expediency, damage, geological and time factors (Shabanov, Alexandrov, 2016).

Results and discussion

Let's enter variables risk grades of $R \in [0;1]$, where R=0 corresponds to lack of pollution, R=1 - to the maximum (total) pollution of the soil oil products.

We build an evolutionary model of the species:

$$x_{t+1}^i = x_t^i + c_t\left(\alpha_i x_t^i + \sum_{j=1}^m \Delta\, x_t^{ij}\right), \qquad (1)$$

where x_{t+1}^i – is the pollution risk of the *i*-th pollutant, *t* is the time, $\alpha_i -$ the evolutionary risk factor due to natural causes, $c_t -$ the empirical factor (determined by the forecast period, data averaging), *m* is the number of pollutants.

As indicators of the contribution of pollutants to total pollution, we use additional risks x_t^i the effects of the associated factors of the region:

$$\Delta x_t^i = x_t^i - x_t^{i_*}, \qquad (2)$$

where $x_t^{i_*}$ – is the risk of the *i*-th pollutant without taking into account the influence of the environment factor at time *t*.

The algorithm for assessing damage due to risks to soil as an evolving system is implemented by the following procedure.

1. Calculation of risk to soil in the interval $(x_t^i; x_t^{i_*})$.
2. Average assessment (on types of soils or vegetation) values of the indicator of weight of pollution g_i (weight of structurally functional changes in the soil), with attraction of monitoring, examinations.
3. Assessment of average value of risk of pollution $\bar{x}_t^i$, with attraction of statistics and laboratory experiments (see below) in the region.
4. Search for relative (%) indicators of z_t^{ij} pollution and s_t^{ij} disposal, corresponding to evolutionary potential and accumulated risks (excluding regional factors).
5. Search for indicators of contamination, disposal from the curve of accumulated risks taking into account all environmental factors (biota).
6. Finding of violations in the soil Δz_t^{ij} and leavings Δs_t^{ij}.
7. Finding of the provided coefficients:

$$k_t^i = \frac{x_t^{i_*}}{\bar{x}_t^i},\ l_t^i = \frac{x_t^i}{x_t^{i_*}}. \quad (3)$$

8. Finding soil pollution and land disposal indicators:

$$\tilde{z}_t^{ij} = z_t^{ij} k_t^i,\quad z_t^{ij} = \tilde{z}_t^{ij}\, l_t^i, \quad (4)$$

$$\tilde{s}_t^{ij} = s_t^{ij} k_t^i,\quad s_t^{ij} = \tilde{s}_t^{ij} l_t^i, \quad (5)$$

where $\tilde{z}_t^{ij}(z_t^{ij}), \tilde{s}_t^{ij}(s_t^{ij})$ are the given values of pollution.

9. We find changes in pollution and land disposal for the *j*-th pollutant and *i*-th soil (plot of land) at time *t*:

$$z_t^{ij} = z_t^{ij} - \tilde{z}_t^{ij},\ \Delta s_t^{ij} = s_t^{ij} - \tilde{s}_t^{ij}. \quad (6)$$

As noted in paragraph 3 of the procedure, we used both statistical and laboratory data. By way of example, one of the laboratory experiments is given (Table 1).

Table 1. Characteristics of oil added to the soil (laboratory experiment, % of the average values for the Perm region)

N	Oil indicator	Result (%)
1	Temperature	78
2	Density	82
3	Pressure	91
4	Water	37
5	Paraffin	19
6	Chloride salts	41
7	Hydrogen sulfide	30
8	Fractions of impurity	54
9	Chlorides (organic)	8
10	Mineralization	72
11	Hydrogen sulfide	30
12	Sulfur	24
13	pH	61

Classification methods were also used in the work, in particular the work of Olhovikova (2018), as well as the ranking of land by their disposal (Kaziev and Shevlokov, 2008) - deserts, heavily shot down land, etc.

Conclusions

The degree of risks and their assessments allow reducing negative impacts, damage to soils in aggregate, by factors, soils and risks. Identification of potential risks according to Russian standards and regulations (GOST 2477-14, 21534-76, 6370-83, 1756-60, 2177-99, 11851-85 and GOST-R 51947-02, 50802-95, 52247-04) will require the use of both laboratory directed experiments and monitoring research. Despite this, the proposed procedure is technological, simple and flexible, allowing entering the mode of self-organization and stability of soil, vegetation cover.

It is obvious that the proposed procedure can be further developed by integrating, for example, procedures of random Markov processes, taking into account probabilities (and time) of transition to a different state of soil, all ecosystems. It is also possible to estimate forecast errors by entropy, with dynamic reassessment of evolutionary parameters of the system. For example, if the estimates given in the procedure (paras. 7-9) are close to optimal, then we have the optimal measure of pollution and disposal of land. It is also necessary to assess the evolutionary potential and adaptation stress of land.

The results of the work are useful for the development of software tools, in particular expert and predictive systems. As the attention of oil and gas enterprises to risk management has increased, the management of the oil complex is becoming more difficult. It becomes multi-critical, multi-factor, so situational models are needed.

References

Alekseenko, V.A. (2013) Chemical elements in geochemical systems. Soil clarks of selitebic landscapes: monograph / V.A. Alekseenko, A.V. Alekseenko. Rostov-On-Don: Publishing House of UFU. -380 p.

Balandina, A.V., Zhilkin, S.M. Kuznetsov, D.B., Dubrovina, S.S. (2015). Recovery capacity of oil-contaminated soils using various preparations // Modern problems of science and education. No.5, pp.716-724.

Barabanshikov, D.A., Serdyukova, A.F. (2016) Environmental problems of the Russian oil industry // Young scientist, №26. pp.727-731. URL: https://moluch.ru/archive/130/35975/

Buzmakov, S.A., Yegorova, D.O., Gatina, E.L. (2017) Dose-effect of soil oil contamination on biotic component of ecosystems // Journal of RUDN. Series: Ecology and Life Safety, vol.25, N2, pp. 217-229. DOI 10.22363/2313-2310-2017-25-2-217-229.

Fetisov, D.V., Kolesnikov, A.N. (2018). Monitoring of subsoil use processes based on processing of aerospace images // News of the Tula State University (Technical Sciences series). Issue 2, Tula: TulGU, pp.216-226.

Gennadiev, A.N. , Pikovsky, Y.I., Zhidkin, A.P., Kovach, R.G., Koshovsky, T.S., Smirnova, M.A., Hlynina, N.I., Tsibart, A.S. (2015) Factors and features of the hydrocarbon status of soils // Eurasian Soil Science. vol.48, №11, pp.1193-1206. DOI: 10.7868/S0032180X15110076

Germanova, S., Ryzhova, T., Kocheva, M., Fedorova, T., Petukhov, N. (2020). Situational modelling of oil pollution risks monitored by distributed monitoring // Amazonia Investiga, vol.9, N25, pp.44-48. URL: https://www.amazoniainvestiga.info/index.php/amazonia/article/view/1025/950

Glukhova, L.V., Kaziev, V.M., Kazieva B.V. (2018) System rules of financial control and management of innovative business processes of an enterprise. Bulletin of the Volga University named after V.N. Tatishchev, vol.2, No.1, pp.118-126.

Ivshina, I.B., Kuyukina, M.S., Krivoruchko, A.V., Elkin, A.A., Makarov, S.O., Cunningham, C.J., Peshkur, T.A., Atlas, R.M., Philp, J.C. (2015). Oil spill problems and sustainable response strategies through new technologies // Environmental Sciences: Processes and Impacts, vol.17, pp.1201-1219.

Kaziev, V.M., Shevlokov, V.Z. (2008) Modelling Land Alienation in Agricultural Complex//International Agricultural Journal, №5, pp.56-58.

Kaziev, V., Kazieva, B., Khizbullin, F. & Takhumova, O. (2019). Increasing the Information Content of Social Network Groups and Clients Using Social Mining // International Conference on Man-Power-Law-Governance: Interdisciplinary Approaches (MPLG-IA 2019). Advances in Social Science, Education and Humanities Research, vol.374, pp.180-184.

Letter from the Ministry of Natural Resources of the Russian Federation "Procedure for determining damage from land pollution with chemicals" (dated 27.12.1993 N04-25/61-5678), URL: http://www.dioxin.ru/doc/N04-25.61-5678.htm

Muzica, O.A. (2011) Bifurcations in nature and society: natural-scientific and socio-synergistic aspect//Modern knowledge-intensive technologies. №1. -pp.87-91; URL: http://www.top-technologies.ru/ru/article/view?id=26640

Olhovikova, N.Y. (2018) Classification of Technologies for Localization and Elimination of Pollution by Phenol-Containing Media // Collection of Theses of the XII All-Russian Conference "Topical Problems of Development of Oil and Gas Complex of Russia" (February 12-14, 2018).

Quen Thi Quinh An, Fazylova D.I., Nazirova A.A., Zenitova L.A., Yanov V.V. (2019). Polyurethane Foam Filled with Chitosan - Sorbent for Elimination of Oil Pollution // Ecology and Industry of Russia, No5, pp.37-41 DOI: 10.18412/1816-0395-2019-5-37-41

Recommendations about identification the contaminated land of February 15, 1995, (1995) [An electronic resource], the access mode: http://docs.cntd.ru/document/902101153

Shtripling, L.O., Kholkin, E.G. & Larionov, K.S. (2016) The technology refinement of soil decontamination contaminated with petroleum products by the reagent capsulation method // Procedia Engineering, vol.152, pp.13–17, http://dx.doi.org/10.1016/j.proeng.2016.07.609.

Shvyryaev, IA, Menshikov, V.V. (2006) Algorithm of comparative risk assessment from emissions of industrial enterprises//Journal of the Russian Friendship of Peoples (ser. "Ecology and Life Safety"), No.2, pp.5-14.

Shabanova, D.N., Alexandrov, A.V. (2016) Integrated risk management as a factor in increasing the competitiveness of oil and gas industry enterprises // Volgograd State. Univ.

(sulfurs. "Economy. Ecology"), No.2(35), pp. 60-70.

Sinha, A., Nagel, C., Schmidt, W., Torondel, B., Boisson, S. (2017) Assessing patterns and determinants of latrine use in rural settings: A longitudinal study in Odisha, India. Int. J. Hyg. Environ. Health 2017, 220, 906–915.

Warriors, V.V. (2018) Bioremediation Method as the Most Effective Method of Soil Purification // International Student Scientific Journal. №3-8. URL: http://www.eduherald.ru/ru/article/view?id=18735