INTEGRATED TOOLS FOR RESTORATION OF OIL POLLUTED SOILS AND WATER BODIES

Nataliya Pankratova, Lyudmila Khokhlova

Abstract: *The integrated tools for modelling and technologies for restoration of oil polluted soils and water bodies are proposed. Application of this tools on the stage of modeling allows to determine the geometrical parameters of pollution, its density, concentration, rate of distribution, to study the forecast and foresight of the spread of contamination and then to efficiently solve the problem of calculating the required volume and concentration of the sorbent. As soon as the stage of modeling is fulfilled and the required volume of the sorbent is defined the stage of the sorbent production is carried out. Technological principles for obtaining of carbon bioactive materials of bio-destructive type and application for purification of soil and water bodies from oil and oil products are used. New environmental technology and methodology consist of creation of a new type of bio-sorptive material, based on natural raw materials, immobilized on the surface of microorganisms-destructors of aboriginal origin with a broad spectrum of action. Created carbon sorbents, based on vegetable raw materials, bio-activated by natural association of oil-oxidizing micro-organisms are effective for the purification of ecosystems from oil pollution, do not require removal from the field of processing and utilization. Implementation of integrated tools for restoration of oil polluted soils and water bodies allows to reduce the period and cost of areas purification.*

Keywords: *integrated modeling tools, forecast, foresight, information platform, microbiological technologies, oil polluted soils and water bodies, utilization, safety*

ACM Classification Keywords: *H.4.2. INFORMATION SYSTEM APPLICATION: type of system strategy*

Introduction

Every year more than 4.5 billion tones of crude oil are produced in the world. Negative consequence of the oil production is an environmental pollution by oil and food processing. Losses during extraction, transportation, processing and utilization of petroleum and petroleum products are inevitable. Everywhere an environmental pollution is carried out spontaneously, without a specific intent. On average, during a year up to 150 million tones of oil are got into the environment, without counting the various accidents with tankers or pipelines. All this had a negative effect on the nature.

Oil pollution first of all threatens marine and coastal ecosystems. Its main reasons are as follows: accidents of oil tankers as a result of collisions, fires or wrecks; leakage of oil from onshore reservoirs; washing of cargo tanks of tankers at the sea. Oil, spilled into the sea water, has many adverse effects on sea life. First of all, it kills the birds, they sink, overheat or deprived of food. Oil blinds animals, living in the water, seals. In the result of pollution, large areas become unsuitable for agricultural use. With incoming of the crude oil and petroleum products in the soil the process of their natural functioning gets broken. Drainage of oil and oil products in the reduced areas of land is accompanied by infiltration into groundwater environment, contributes to the pollution of underground rivers and water bodies.

Continuous strengthening of human impact on nature, environmental, technological processes in the world, and especially the development of oil and oil processing industry, the contamination with oil and oil products in conflict zones or in areas, exposed to terrorist attack, provoke ever-growing negative impact, especially on the ecological environment. The problem of cleaning soils from oil pollution, development of new technologies of restoration of oil-polluted lands is a high priority problem. Oil discharges and accidental oil spills are a particularly important problem, because it often causes contamination of the underground water and drinking water sources. The consequence of such actions is a significant deterioration in quality of life for people throughout the world. The urgency of this problem is also caused by major material damage, which is applied in different regions of the processes of contamination of soils and water bodies with oil and oil products, as well as the costs of environmental renovation of contaminated areas. Oil pollution is the essence of environmental threats, with which every country risks to face every day and hour.

The preservation of the environment during accidental spills of oil and petroleum products is increasingly focused on all over the world. Solution of problems related to pollution prevention and conservation of natural ecological systems, is sought in various oil and gas companies, academic institutions, public. Despite the technological developments of the mechanical collection of oil, each new incident usually ends up with 80-90% of the oil remaining in the water body and soil. Known methods for environmental clean-up of oil demand to improve their operational capabilities, focus them on a solution of the problems of pollution disposal, regardless of environmental conditions and the environmental safety of implementation.

The absence of a modeling tool set of natural and manmade disasters does not allow timely and systematically implementing their prevention, foresight and forecast. In this paper the integrated modeling tools of modeling and microbiological technologies for restoration of oil-polluted soils and water bodies are proposed.

The only feasible way of dealing with oil spills nowadays is a complex of measures, including modelling, new technology, safety, low cost and high effect. Proposed toolkit is based on the synthesis of modeling and technology of cleaning soil and water from oil products.

1. Integrated Tools Set of Modeling and Microbiological Technologies for Restoration of Oil-polluted Soils and Water Bodies

The proposed paper presents of an integrated tools of modeling and microbiological technologies for restoration of oil-polluted soils an, scientific ground for expedience of application of bioactive materials in the region on the basis of the technological foresight methodology, forecasting processes and mathematical models, methods of system analysis, as well as the technological principles for obtaining carbon bioactive materials of bio-destructive type and their application for clearing soil and water bodies from oil and oil products. Scheme of an integrated modeling tools and microbiological technologies for restoration of oil-polluted soils and water bodies is shown in Fig 1.

The adaptation of mathematical models, according to realistically investigated contaminated soil and water bodies, is realized. These models are based on equations of mathematical physics, allowing to estimate the boundaries of latent contamination, the parameters of the distribution pollution, the concentration sphere of the pollutant, the points and areas to maximize its content, direction and rate of its drifting in the environment [Pankratova N.D., Zavodnik V.V., 2004]. The modified methods of hidden Markov chains are used to determine the probability of generating the parameters of the spread of pollutants, improve the quality of the whole modeling process and evaluation of foresights that provide a distribution sphere of harmful substances in water-saturated soil layer and solid. The adequacy of the constructed mathematical models and their compliance with the basic dynamic processes, which occurred in biological systems subjected to anthropogenic impacts and the

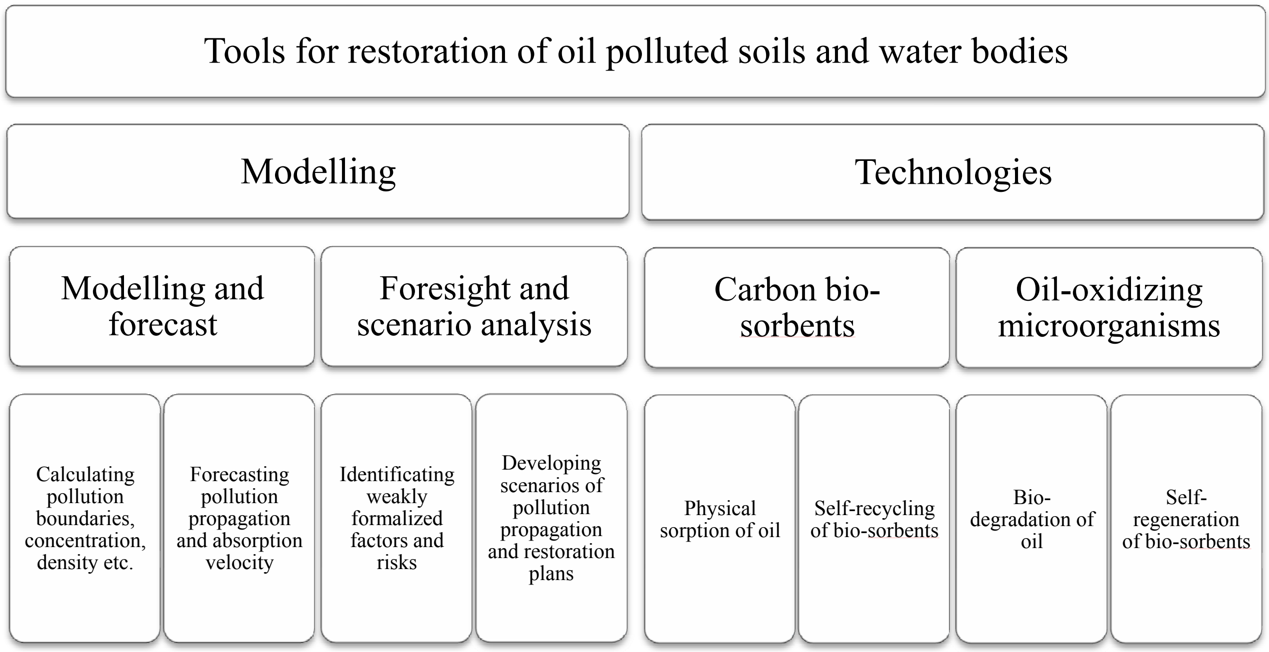

Figure 1. Scheme of an integrated modeling tools and microbiological technologies for restoration of oil-polluted soils and water bodies

effectiveness of the proposed approaches to the control of natural restoration processes and technology systems are shown. The new and modified methods of system analysis as the most universal and confirm to the current requirements are applied [Zgurovskiy & Pankratova, 2007]. In its turn, this kind of analysis is the application of the methodological, mathematical and organizational tools, which are designed to identify internal and external relationships and interactions between the processes of object - as elements of one or multitypical and natural in origin, the means of description, the estimation of parameters, modeling, and as a consequence - forecasting and scientific foresight. This allows to build and evaluate alternative options for the application of bioactive materials in the region, taking into account objective information and expert opinions on the state of the region. In its turn, it allows the decision maker to get the most complete, accurate and most important, timely information about possible or unavoidable adverse impacts of hazardous processes of eco environment.

The production of biosorbents is based on adsorptive material with immobilized oil-oxidizing microorganisms, which have the ability to localize and destroy oil and oil products in their localized state. Destruction of oil can be conducted up to the last stages, when only products of oil are left, which are carbon dioxide, water and other ecologically inert components. The residual part of the biosorbent is the initial base of the sorptive material. The process of oil biodestruction is conducted both on the surface and in the deeper layers of ground. Biosorbents often are the only means of dealing with oil pollution. Application of sorbent of this type allows quickly and effectively localizing accident-related oil spills and providing the destruction of oil and oil products.

The cleaning of oil-polluted areas has certain peculiarities. Given the large adsorptive surface, soils can accumulate pollutants. The sorptive capability depends on the properties of soils, primarily capillary forces, that are defined by the granulometric composition of the soil and its moisture. Dependence of migration and accumulation of oil and oil products in soil and moisture level of soils is confirmed by experiments and proved by calculation methods. Higher levels of moisture in soils decrease the possibility of oil binding in soil and provide its high radial transfer activity. Penetration of oil in the environment (soils, water bodies) disturbs and distorts the natural processes: it oppresses the breathing activity and microbial self-purification; changes the ratios between different groups of microorganisms, altering the metabolism processes; suppresses nitrogen fixing and nitrification, causes accumulation of non-oxidizable products.

Modelling of microbial technology of oil-polluted soils and water bodies restoration is based on the methodology of estimation the environmentally hazardous processes of different nature on the basis of a priori existing monitoring data, expert assessments and technology foresight. Interaction and interdependence of the same type and different types of processes are identified and taken into account.

For correct restoration of polluted soils it is necessary to know the distribution and investigate of contamination. The migration of pollution in ground water is determined among over by geological conditions of the surface layers of soil. Analysis of pollution distribution is made by numerical simulations using programs, which are based on the finite element method.

As a result of researches, the optimum parameters of microbial biodegradation and sorption binding of oil components, depending on conditions of medium, are revealed. Optimum technological conditions of reception carbon sorption materials of destructive type, based on natural raw materials, will be determined.

The proposed strategy is aimed at creating a tool of modeling that allows to determine the boundaries, concentration, density and velocity of pollution distribution, and develop a new technology for enhancing the environmental self-purification ability of anthropogenic pollution of soils: implementation of pollutant contact with microorganisms-destructors in the sorptive material, purification of soil environment by reducing the concentration of mobile part of the contaminant as a result of binding and degradation of complex microbial-degraders.

2. Stage of Modelling for Restoration

Stage of modelling is a scientific basis for the calculation of field distribution of oil pollution. This allows to determine the geometrical parameters of pollution, its density, concentration, rate of distribution, study the forecast and foresight of the spread of contamination and then efficiently solve the problem of calculating the required volume and concentration of the sorbent. Traditionally, this stage is absent when the cleanup of soil and water from pollution with oil and evaluation of these parameters is not performed. Such a strategy without justification forecast and foresight often leads to significant long-term process of restoring soil and water pollution and increasing of its cost.

Some of the mathematical models are presented with (1)-(6) equations [Pankratova N.D., Zavodnik V.V., 2004].

A mathematical model of the filtration process and the transfer of harmful impurities is described in the following statement

$$\frac{\partial Q(t,z)}{\partial t} = -(\boldsymbol{u}, gradQ\ (t,z)) + \sum_{i=1}^{3} \frac{\partial}{\partial z_i}(\mu(t,z)\frac{\partial Q(t,z)}{\partial z_i}) + \sum_{i=1}^{N} U_i^Q(t)\delta(z - z^i) \quad (1)$$

under initial $Q(t.z)\big|_{t=0} = Q_0(z)$

and boundary conditions on the lower and upper boundary of water-saturated layer

$$\frac{\partial Q(t,z)}{\partial \boldsymbol{n}} = 0,$$

and on the lateral boundary of water-saturated layer

$$\frac{\partial Q(t,z)}{\partial \boldsymbol{n}} = \lambda(Q_{out} - Q_{in}),$$

where Q is the spatial-temporal field of concentration of harmful impurities.
The equation (1) describes the physics of the process of distribution in three-dimensional spatial region of

parallelepipedic type, where: u is the vector of convective transfer, μ is field of turbulent diffusion, U is power of producing wells (total N), represented as a point with topographic precise positioning through δ - Dirac function.

For the calculation of values of convective transfer vector (2)

$$\boldsymbol{u} = -k(t,z)\mathrm{grad}X(t,z) \qquad (2)$$

the evolutionary model of the pressure field $X(t,z)$ is represented by the following equation

$$b(t,z)\frac{\partial X(t,z)}{\partial t} = \sum_{i=1}^{3}\frac{\partial}{\partial z_i}(k(t,z)\frac{\partial X(t,z)}{\partial z_i}) + \sum_{i=1}^{N}U_i^X(t)\delta(z - z^i) \qquad (3)$$

under initial $X(t.z)\big|_{t=0} = X_0(z)$

and boundary conditions on the lower and upper boundary of water-saturated layer

$$\frac{\partial X(t,z)}{\partial \boldsymbol{n}} = 0,$$

and on the lateral boundary of water-saturated layer

$$\frac{\partial X(t,z)}{\partial \boldsymbol{n}} = \lambda(X_{out} - X_{in}).$$

In this case, the field of the reservoir pressure in water-saturated layer is calculated; b is the field of porosity of the environment, k is the field that defines the attitude of the permeability to the viscosity of the medium.

The description of the model of identification of the turbulent diffusion field is described with the help of (4)-(6). The quality criteria of identification, which is needed to be minimized, is introduced (4), the derivative from the target parameter of Lagrangian is recorded (5) and step-by-step iterative procedure (6)

$$J(\mu) = \int_0^T \sum_{i=1}^{M}\left(Y_Q(t,z^i) - Q(t,z^i)\right)^2 dt \qquad (4)$$

where (0,T) - period of time when the measurements of concentration of the investigated substance in the i-th measuring well were made; $Y_Q(t, z^i)$ is function of natural measurements taken in the measuring wells.

L{.} – Lagrangian, introduced during the transition from the minimization problem, has the form:

$$\frac{\partial L(\mu)}{\partial \mu} = \int_0^T \sum_{i=1}^{3}\frac{\partial Q(t,z)}{\partial z_i}\frac{\partial P_Q(t,z)}{\partial z_i}dt. \qquad (5)$$

Restrictions for the identifiable parameters following from the physics of the process

$$0 \le \mu_i \le \mu(z) \le \mu_{\hat{a}}$$

and iterative procedure

$$\mu_{s+1} = \mu_s - \lambda_\mu \frac{\partial L(.)}{\partial \mu_s} \qquad (6)$$

is fulfilled.

$P_Q(t,z)$ (5) is the solution of the dual problem written in the form

$$-\frac{\partial P_Q(t,z)}{\partial t} = -(\boldsymbol{u}, gradP_Q(t,z)) + \sum_{i=1}^{3} \frac{\partial}{\partial z_i}(\mu(t,z)\frac{\partial P_Q(t,z)}{\partial z_i}) + 2\sum_{i=1}^{M}(Y_Q(t) - Q(t,z^i))$$

under boundary conditions

$$\mu(t,z)\frac{\partial P_Q(t,z)}{\partial n} = P_Q(t,z)$$

and initial conditions

$$P_Q(t,z) = 0$$

Proposed models are based on equations of mathematical physics, allowing to estimate the boundaries of latent contamination, the parameters of the distribution pollution, the concentration sphere of the pollutant, the points and areas to maximize its content, direction and rate of its drifting in the environment.

In order to combat oil pollution it is important to know the main characteristics of the oil slick, which could be most easily found from forecasting mathematical models, which include:

- forecasting based on different time series models;
- exponential smoothing;
- model of linear growth;
- Bayesian networks technique.

All of the named methods and techniques were scientifically proved and tested in a number of projects. Many of these methods were significantly improved compared to the analogues that are used in the world.

On the basis of proposed models the following problems are solved:

- identification of boundaries and depth of the affected environment;
- identification of the physical characteristics of the environment;
- purification velocity of the used sorbent for cleaning the contaminant – oil inclusions;
- short-and medium-term forecast of the processes of spreading and dissipation of pollutants;
- minimization and optimization of the places where sorbent is used;
- minimization and optimization of the placement and operation modes of the gaging equipment;
- computer graphics implementation of the simulation results in a given time scale.

The methodology of the modeling tool is based on technology foresight in the context of sustainable development, which is developed in the form of information platform of system analysis, without analogues in the world [Pankratova N.D., 2010; Pankratova N.D., 2004]. Solutions for the investigated oil contaminated regions should be taken in the form of scenarios and strategies for their development considering their current characteristics. The construction of these scenarios is provided by means of a universal set of tools and approaches, called the methodology of scenario analysis, which is constantly being developed and improved at IASA [Pankratova N. D., Savastiyanov V. V., 2009]. The methodology of scenario analysis is based on a consistent implementation of the main stages of technological foresight. In the first phase the problem and the object of forecast are studied using the methods of qualitative and quantitative analysis, then the qualitative and quantitative information is given to a single platform. The sequence of individual methods is determined and the relationship between them is established. This allows us to continue building a holistic process of foresight and develop a group of future scenarios for the object of foresight. In this case, evaluation of alternative options for scripting can be done on the comparison of multiple criteria (economic, environmental, political, social, etc), as well as the situational, unpredictable, unavoidable and other risks. Analyzing the characteristics and features of each of the developed scenarios, a group of people who make strategic decisions, select the most appealing scenario, develop a plan of action concerning the object of foresight and ensure the implementation of this plan.

On the basis of foresight technology and methods of forecast the following problems are solved:

- Scientific ground of application expedience of bioactive materials in specific region on the basis of the technological foresight.
- Identify the causes of the pollution.
- Definition the geometric (3-D) of the border pollution.
- Calculation of the concentration of the field of pollution.
- Calculation of the trend of the pollution.
- Determination of risks that have emerged due to the presence of pollution.
- Calculating the required volume (and quality) of the sorbent.

The following modified methods of qualitative analysis involved in foresight process are used:

- Delphi method;
- analytical hierarchy method;
- morphological analysis method;
- cross-impact analysis method.

3. Stage of Microbiological Technologies for Restoration

As soon as the geometric parameters and the concentration of pollution and the required volume of the sorbent are defined the stage of the sorbent production is carried out. Technological principles for obtaining of carbon bioactive materials of bio-destructive type and application for clearing of soil and water bodies from oil and oil products are developed.

Global positive and negative experience in dealing with oil pollution has caused the development of integrated technologies, using a new group of bio-sorbents, which are not only sorptive and physical-chemically active concerning petroleum, but are also biological, which means the ability to degrade oil, due to biodegradation.

Concerning that, it is necessary to develop new and improve existing technical and technological solutions that will allow quickly and effectively eliminating the effects of oil spills. New environmental technology and methodology consist of creation of a new type of bio-sorptive material, based on natural raw materials, immobilized on the surface of microorganisms-destructors of aboriginal origin with a broad spectrum of action [Patent of Ukraine № 43974, L.Khohlova, D. Shvets, A. Khohlov; Patent of Ukraine № 43965, L.Khohlova, D. Shvets, A. Khohlov].

Distinctive features of bioactive bio-sorptive material are as follows:

- it locates oil slick throughout the mass and volume and destroys the sorption-related oil, due to biodegradation;
- microorganisms-destructors are fixed on the carrier units, not inert, and sorption-active to the pollutant and to the very microorganisms-destructors;
- introduction of a consortium of microorganisms-destructors of oil aboriginal descent in the environment, which are previously isolated from different contaminated sites and immobilized on the surface of the oil-sorptive material, that provides increased destructive activity and resistance to various unfavorable conditions;
- prolonged action of the material due to self-regeneration as a result of biodegradation of oil pollution;

- high retention capacity in relation to different types of crude oil (petroleum), and biocompatibility with microorganisms-destructors of aboriginal origin;
- selfrecycles during the cleaning facility (there is not required to remove the material of biodegradable type from places of processing).

Merits of the proposed technology lie in the fact that a solution for the problem of bioremediation of oil-polluted ecosystems, using oil-absorptive materials of biodegradable type, is proposed. It is essential to create biodegradable materials, where micro organisms-destructors are fixed on the carrier unit, not inert, and sorption-active to the pollutant, and to the very micro organisms-destructors. Making such bio-sorptive complexes in the ground will allow implementing the closest spatial orientation of the oil-oxidizing micro-organisms and petroleum hydrocarbons, sorptionly connect a significant part of residual oil in the ground, and completely eliminate its toxic adverse effect by increasing the destructive capacity of the biological component of the material.

Created carbon sorbents, based on vegetable raw materials, bio-activated by natural association of oil-oxidizing micro-organisms, meet this case; they are effective for the purification of ecosystems from oil pollution, do not require removal from the field of processing and utilization. Making such bio-sorptive complexes in the ground will allow implementing the closest spatial orientation of the oil-oxidizing micro-organisms and petroleum hydrocarbons, sorptionly connect a significant part of residual oil in the ground, and completely eliminate its toxic adverse effect by increasing the destructive capacity of the biological component of the material.

The conditions of immobilization of natural indigenous consortium of microorganisms-destructors of oil on the surface of oil-sorptive materials and ability to hold nutrients and xeroprotectors, which will be introduced in bio-sorptive complex for improvement of sorptive and destructive characteristics of the material, will be justified.

The research of adsorptive and destructive properties of oil-sorptive biologically active sorptive materials regarding the oil samples of different origin will determine the practical implementation directions of technology of manufacturing and application of effective ecologically clean biosorbents for localization and destruction of oil pollution.

Admissible concentration limits (ACL) of oil pollution in soils depend on the type of oil product, its value is 0,1 mg/kg for soils. However, the ACL of total content of oil products in soils is not standardized; only the ACL for several types of oil products: 0,3 mg/kg for benzol, 0,3 mg/kg for toluol; 0,3 mg/kg for xylol. Minimal concentration level of oil products in soils is considered safe upper level of concentration, violation of this level causes degradation of habitat quality. Safe upper level of concentration of oil products depends on a combination of various factors, including type, composition and characteristics of soils, climate conditions, type of oil products, purpose of land use etc.

Oil spills are characterized by a combination of ecological factors: 1) unique multicomponent, often changing composition of oil; 2) heterogenity of composition and structure of an ecosystem, which is in constant flux; 3) variety and changeability of external factors influencing the ecosystem: temperature, air pressure, humidity, atmospheric and hydrospheric conditions etc. The consequences of polluting ecosystems with oil and measures for elimination of these consequences can be planned only with consideration of those three groups of factors.

4. The Benefits of Successful Implementation of the Integrated Tools

The main goal of the proposed strategy is to guarantee a rationally justified reserve of survivability of a complex system in real conditions of fundamentally irremovable information and time restrictions.

The main idea of the strategy is to ensure the timely and credible detection, recognition, and estimation of risk factors, forecasting their development during a definite period of operation in real conditions of a complex objects operation, and on this basis ensuring timely elimination of risk causes before the occurrence of failures and other undesirable consequences.

The benefits of successful implementation of the integrated tools are as follows:

- return of the restored areas into economic use;
- recultivation and fertility increase of the land;
- preventing the possibility of oil penetration into underground water layers;
- increase in quality of life for people in the region;
- strengthening of NATO positive image and improvement of public mood.

The cost of land restoration includes:

- data collection, monitoring, gathering samples of soils for the area;
- research and detailed analysis of the problem;
- manufacturing, transfer and spread of sorptive materials;
- organizational activity and popularization.

The average expenses on cleaning soils from different types of oil products and needed amount of biosorbent's consumption are provided in the table 1.

Table 1. Average expenses on cleaning soils and needed amount of biosorbent's consumption

Type of oil product	Area of spill, m^2	Depth of contamination, cm	Consumption of biosorbent , kg	Calculated cost of biosorbents, $
Raw oil	1	1	2	20
	1	15	15	150
	10	1	20	200
	10	15	150	1500
	100	1	270	2700
	100	15	1200	12000
Diesel fuel	1	1	1,5	15
	1	15	10,5	105
	10	1	15	150
	10	15	175	1750
	100	1	150	1500
	100	15	750	7500
Kerosene	1	1	5,8	58
	1	15	10,5	105
	10	1	18	180
	10	15	90	900
	100	1	180	1800
	100	15	950	9500
Fuel oil	1	1	2,5	25
	1	15	18,5	185
	10	1	35	350
	10	15	125	1250
	100	1	250	2500
	100	15	1250	12500

Amount and expenses of biosorbent for cleaning of water bodies is calculated based on the area of oil spill.

Technical processes of putting biosorbents into oil contaminated areas consist of scattering biosorbents over polluted areas using any effective dispersing tools. Before the start of cleaning, the amount of oil that should be gathered is calculated taking into consideration the area of spill, depth of contamination and density of the pollutant.

Biosorbents can be disperssed over the contaminated areas in different ways (pulverization, scatter, etc.). The average amount of needed sorbent is 1 kg for each 4 kg of oil product if urgent localization is needed and 1 kg for each 8–10 kg of oil product under normal conditions. Cleaning of oil-polluted soils is conducted by loosening of soil and scattering the biosorbents over it, using 1–2 kg of material for each 1 m^2 of surface. Contaminated areas must be treated with foaming materials beforehand.

Fig. 2 Process of water bodies purification

After cleaning of water bodies the biosorbents, saturated by oil products, gradually sink to the bottom and utlilze themselves as a result of oil product biodestruction. The process of water bodies purification is shown on Figure 2. After cleaning of solid surfaces the biosorbents, saturated by oil products, are moved to a sump, where they utilize themselves as a result of oil product biodestruction.

4. Conclusion

The proposed integrated tools for modelling and technologies for restoration of oil polluted soils and water bodies allows to prevent and eliminate pollution of soil and water areas with xenobiotics (oil, petroleum products, pesticides) includes the following objectives:

- developing and implementing a modeling tool set for scenario analysis in the region of study in the form of information platform of system analysis software;
- developing a mechanism allows to determine 3D parameters of oil-contaminated territories; the oil pollution concentration and dencity; the dynamics of oil pollution distribution;
- developing technology for restoration of oil polluted soils and water bodies from xenobiotics (oil, petroleum products, pesticides) which is based on creation of a new type of bio-sorptive material, based on natural raw materials, immobilized on the surface of microorganisms-destructors of aboriginal origin with a broad spectrum of action;
- cleaning of territories using the developed technologies on a scientifically grounded basis.

Received scientific and technological results will be used to create new, the most effective bioactive oil-sorptive materials of destructive type, intended for liquidation of oil pollution in ecosystems of different composition.

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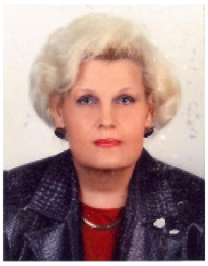
Authors' Information

Nataliya Pankratova - *DTs, Professor, Depute director of Institute for applied system analysis, National Technical University of Ukraine "KPI", Av. Pobedy 37, Kiev 03056, Ukraine; e-mail: natalidmp@gmail.com*

Major Fields of Scientific Research: System analysis, Theory of risk, Applied mathematics, , Applied mechanics, Foresight, Scenarios, Strategic planning, Information technology



Ludmila Khokhlova - *Senior Researcher , PhD degree (Technical sciences),*

Institute for Sorption and Problems of Endoecology NAS of Ukraine, 13 General Naumov Str., Kyiv, Ukraine; e-mail: lkhokhlova@ukr.net

Major Fields of Scientific Research: Ecology; Environmental Technology; Monitoring of pollution of ecosystems; Physical chemistry.