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TECHNICAL NOTE

Performance Evaluation of Oily Waste Treatment Technology

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ABSTRACT

On the basis of oily waste treatment in Russia which has been described in this article and on the example of oil-contaminated soil (OCS) treatment, one can be considere two most widespread technologies: bioremediation and thermal recovery. We developed the process flow sheet of the equipment (UT-2S) for industrial oily wastes treatment on the basis of high temperature air tight decomposition of oily waste. We have also worked out criteria of prime cost, OCS treatment period as well as OCS purification efficiency and industrial emission of harmful substances of each technology of oily waste treatment with the aim of its comparison. The analysis of the results recorded during this work makes possible to find out advantages and disadvantages of OCS recycling technologies and to evaluate efficiency of each process. The thermal recovery appears to be more profitable for the treatment of a large amount of oily waste.

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1. INTRODUCTION

Oily waste which is being produced in the course of oil production, processing, transportation and further use of oil products is a subject to obligatory disposal. A fine of up to $15,000 shall be paid by any enterprise for non-compliance with the terms and conditions of ecological safety according to the Federal Law №7 on environmental protection [1]. Therefore the oil-extracting companies quite often fall back on the cheapest ways of oily waste treatment. Oil spill on soils and ground is the key problem of environmental pollution by oily waste on the territory of the Russian Federation. The oil-contaminated soil (OCS) must be disposed or recovered according to ambient quality standard.

It is necessary to point out the following types of solid and liquid industrial and particularly oily wastes treatment such as chemical, mechanical; burning out; phytomeliorative and biological methods; and thermal neutralization.

Chemical method is based on use of the reactants causing oxidative breakdown of oil hydrocarbons. Chemicals and other decomposition products (such as carcinogenic and mutagenic substances - benzopyrene, phenols, polycyclic hydrocarbons, etc.) pose a greater risk than primary oil pollution. Chemicals can cause uncontrollable mutations and bring to irreversible change of biocenosis that has unbettered consequences for living organisms. But chemical ways of treatment are unacceptable for ecological purposes, especially in town industrial zone.

Mechanical method is based on waste localization, bunding and further burial. Obviously that does not completely solve a problem of oil waste cleanup but it provides transferring from one place to another.

The simplest of physical method is the burning out; however, it dangerously contaminates the environment by the harmful toxic compounds. Reduction of the harmful substances influence on the environment needs additional expenses which bring to the increase of cost of works [2].

Phytomeliorative and biological methods are effective at the low level of soil contamination as the final stage of decontamination but they demand the ground with appropriate infrastructure [3].

Bioremediation (technology I) and thermal utilization (technology II) are distinguished as the main technologies of oily waste treatment in Russia.

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Both of these techniques of oily waste (OW) decontamination are directed on its treatment up to non-hazardous level of polluting substances content which does not affect to the inhibition of biological processes and not suppresses growth of plants.

2. THE MAIN TECHNOLOGY OF OILY WASTE TREATMENT IN RUSSIA

Main technology of oily waste treatment:

- ✓ Oily soil taken from the places of accidental oil spills and operation of wells and oil pipelines;
- ✓ Solid waste of processing of liquid oily wastes or oil slime from emergency and technological barns or slurry reservoir after release from a liquid-side.

Process of bioremediation is based on intensification of natural decomposition of hydrocarbons by introduction of mineral and organic fertilizers as well as biological preparations obtained from the natural flora of the polluted and being decontaminated soil [4, 5]. Processing of OW on the basis of bioremediation by biological products and fertilizers is made annually according to production techniques [6]. Natural organic substratum comes as fertilizer and it might be peat, well humus-enriched soil, dead plant materials etc. Organic fertilizers improve the water-air mode of the substratum before bioprocessing and decomposition of oil microflora. Process of oil-contaminated soil treatment on the basis of bioremediation takes 3-7 years depending on extent of soil pollution.

Oily waste thermal recovery is produced with the use special-purpose equipment. There is a wide range of such equipment with various design and technological principles not all of which however can provide effective recovery. Most of them have unfairly difficult design and impossibility to use returnable warm of pyrolysis gases that leads to raw material losses and the increased power consumption, low level of OCS purification due to uneven temperature distribution on the retort surface directly contacting to treated waste. We developed the process flow sheet of the equipment (UT-2S) for industrial oily wastes treatment on the basis of high temperature air tight decomposition of oily waste. The equipment is executed from separated functional modules (unit) that provide the maximal density of configuration and access to devices for its service and repair [7]. The method of thermal decomposition is based on pyrolysis - destruction of organic part of waste as oil slime at a temperature of 500-550°C with fixed residue and combustible gas. The main feature of thermal recovery on the offered equipment is pyrolysis in the rotating muffle furnace with a "pipe-in-pipe" retort system without air access, thus the combustible gases which are allocated at pyrolysis are completely burned in a furnace fire chamber and combustion gases are used for heating of a retort.

The scheme of thermal soil recovery equipment as well as a complex of works starting with initial raw materials preparation and finishing with cooling and warehousing of the recovered soil is shown in Figure 1.

The oily material comes to the S-1 mixer where for loosening. Then conveyors K-2 and K-3 via bin B-1 transfer the material to a retort of the muffle furnace P-1 for thermal influence at a temperature 400-700ºC. The needed temperature is reached by heating the air in the course of fuel oil burning in a fire reheating chamber P-2 from the very start of the process. Diesel fuel supply stops as soon as the necessary temperature is gained. Further heating of a retort is retained by combustion gases. Due to the lack of air in the furnace there is a stable process of oily fractions decomposition. The flue gas is pumped out from the furnace by the D-1 smoke exhauster and carried off to a chimney Td-1. Full period of a ton of oil-contaminated soil recovery takes 1-2 hours depending on the chosen mode of the equipment.

3. METHOD AND RESERCH

The following criteria analyze the efficiency of both techniques of oil-contaminated soil recovery:

- ✓ Oil-contaminated soil purification rate;
- ✓ Prime cost of a ton of oil-contaminated soil recovery;
- ✓ Ecological factor of treatment (industrial emissions into the atmosphere) [8, 9];
- ✓ Duration of oil-contaminated soil recovery.

Degree of treatment is accepted as the relation of initial degree of pollution of OCS (before recovery) to final stage (after recovery). For definition of soil treatment rate, bioremediation for the quantitative chemical analyses (QCA) of samples from various working zones of landfill was carried out. Evaluation of pollution degree (amount of oily waste in 1 kg of soil) was conducted by the use of electronic scales (Table 1).

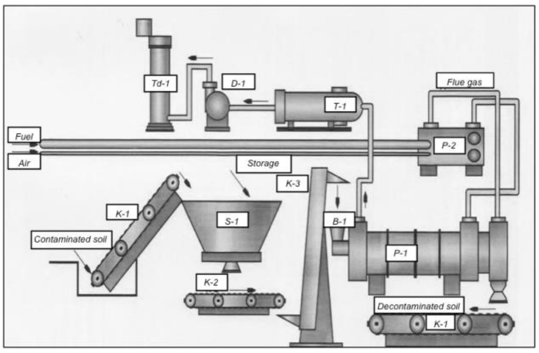

Figure 1. Scheme of thermal soil recovery equipment UT-2C

TABLE 1. QCA **analyses** of soil samples (technology I)

№	Soil sampling point	Amount of oily waste in soil, mg/kg			
		Initial soil	Period of recovery, years		
			1	2	3
1	Work zone №1	35360	18780	16620	15800
2	Work zone №2	34130	19920	14710	12740
3	Work zone №4	28700	21020	17320	13700

In accordance to measurements there was structured the dependence of amount of oily waste in soil on defined period (Figure 2). The quantitative chemical analysis showed considerable intensity of waste neutralization after the first processing. After the second and third processing the removal rate decrease slows down in process. The removal rate by bioremediation for the considered period (3 years) was determined 55.32%.

Samples were taken from initial oil-contaminated soil before recovery and finally after processing by thermal processing on UT-2S installation. Results of QCA of the soil samples are shown in Table 2. According to obtained data of QCA the removal rate of technology II reported to be to 99.5%.

Prime cost of oil-contaminated soil treatment was defined from the attitude of full costs on each technology of treatment towards amount of the soil recovery. Fixed costs of bioremediation are represented by rent of the land plot (in the case of 9 hectares), purchase and rent of the special equipment for processing of the contaminated soil by active agents and fertilizers.

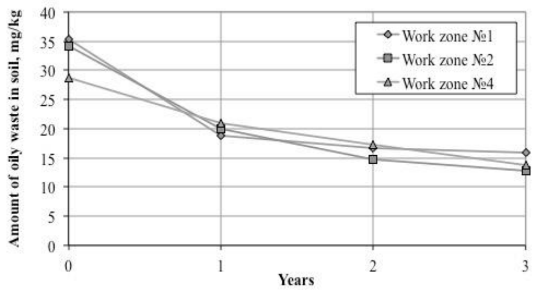

Figure 2. Dependence of amount of oily waste in soil on the period

TABLE 2. QCA analyses of soil samples (technology II)

№	Type of oil-contaminated soil	Amount of oily waste in soil, mg/kg
1	Initial soil	76400
2	The soil after the thermal recovery	400

Variable costs are represented by salaries, costs on fuel, chemical reagents, fertilizers and depreciation charges. Fixed costs of the thermal recovery are represented by rent of the land plot (1 hectare), cost of UT-2C special equipment and installation and variable costs are salaries, costs of fuel and depreciation charges. All expenses are presented in Table 3; data are reported in conventional units for the period of 1 year.

On the basis of the obtained data there was structured dependence of total costs on period (figure 3).

On the land plot of 9 hectares the maximum quantity of the treated oil-contaminated soil by bioremediation equals to 11700 tons. Installation productivity for the considered time period was 26100 tons. According to Table 3 and Figure 3, the prime cost of a ton of oil-contaminated soil in the period of 3 years equals to 0.005 conventional units by bioremediation and 0.0026 conventional units by thermal recovery, which in relative units is equal to 1 and 0.52 respectively.

TABLE 3. Costs for bioremediation and thermal recovery

Type of costs	Technology I	Technology II
Fixed cost, conventional unit.[2]		
Rent of the land plot	0.9	0.1
Special installations	-	25
Special equipment	6.5	3.2
Total	7.4	28.3
Variable cost		
Fund of salaries	1.28	1.16
Fuel	1.73	10.74
Chemical reagents	2.11	-
Fertilizers	10.73	-

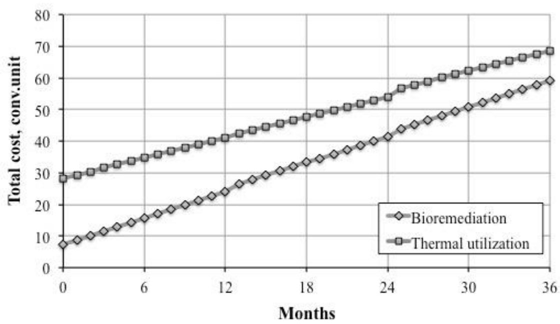

Figure 3. Dependence of cost of technology I and technology II on the period

[2] A conventional unit is cost of rent of 10 hectares of the land plot.

The soil treatment is carried out on the basis of the Federal law "About environmental protection" and resolutions of the Government of the Russian Federation dated January 27, 2009 № 53 "About implementation of the state control in the field of environmental protection (the state environmental control)". According to the legal acts the amount of the polluting substances in atmospheric air in the process of oil-contaminated soil recovery should not exceed the maximum permissible concentration (MPC) [10]. There was carried out QCA in the place of the oil-contaminated soil recovery by means of the PE 5300V spectrophotometer under the atmospheric pressure and environmental temperature of 13ºC. The results of measurements are shown in Table 4.

For estimating the level of industrial emissions in the atmosphere in the process of oil-contaminated soil treatment by means of UT-2C installation, the quantitative chemical analysis was carried out by means of the "Expert" gas analyzer (Table 4).

Per totality of industrial emissions after oil-contaminated soil recovery and of treatment technologies the relative ecological factor (a ratio of concentration of the polluting substance to maximum concentration limit) amounts to 0.1 and 0.293, respectively.

For the considered techniques of oil-contaminated soils treatment by criterion of the period joint costs of two technologies were equated. Thus, the cost of 11700 tons of OCS treatment for the min. term (3 years) equals to 59.08 conventional units for bioremediation. The period of thermal recovery at the same joint costs equals to 2.28 years that in relative units equals to 1.0 for technology I and to 0.44 for technology II.

For comparison of both methods it is necessary to lead the specified criteria to "positive" or to "negative" factors. Prime cost, period and ecological factors are negative, i.e. its growth brings to economic and ecological efficiency decrease and growth of removal rate brings to increase. Therefore, the removal rate is performed as the reverse index - amount of residual waste. The residual waste index equals to 44.78% for bioremediation and to 0.5% for thermal recovery.

TABLE 4. Results of QCA of the atmospheric air

№	Concentration of gas in the air, mg/m^3			
	Name	TechnologyI	TechnologyII	MPC
1	Nitrogen dioxide	0.02	0.027	0.2
2	Nitrogen oxide	-	0.004	0.032
3	Carbon oxide	-	0.013	0.384
4	Sulfur oxide	-	-	0.5

4. RESULTS

The comparison of both methods of OCS treatment is shown in the chart (Figure 5) which was constructed on the basis of defined criteria and counted relative values. The given chart shows the effectiveness of thermal recovery. Quality of purification of the OCS by thermal recovery is much higher in comparison with technology of bioremediation. Prime cost and period of a ton of OCS treatment by thermal recovery is twice as low as technology I. However, the level of industrial emissions during the working process of the UT-2C installation higher than when using of technology of bioremediation by three times, but it does not exceed maximum permissible concentration [3, 8].

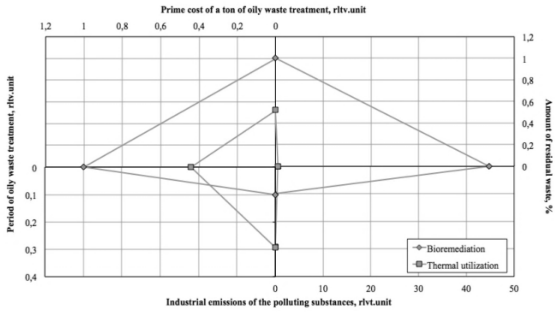

Figure 5. Diagram of oily waste treatment efficiency

5. CONCLUSION

Thus, we can see the greatest efficiency of the technology II on a number of criteria. And however it demands considerable financial expenses the thermal recovery appears to be more profitable for treatment of a large amount of waste including paraffin after repair of wells. The initial content and component composition of oil contaminated wastes does not play a role on the quality of thermal utilization. Thermal utilization of oil contaminated wastes is a universal, highly efficient method for any region of oil production.

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چکیده

این مقاله یر پایه تصفیه پساب نفتی بوده و نمونه ای از خاک آلوده به مواد نفتی بر حسب تکنولوژی متداول به دو روش بیوریمیدیاسیون و تکنولوژی بازیافت حرارتی مورد بررسی قرارداده است. در این مقاله شمای فرایندی با واحدها و دستگاههای طراحی شده ارائه گردید. این تکنیک قادربه تجزیه حرارتی مواد و پساب نفتی می باشد. ما همچنین به هزینه های فرایند و بازدهی آن برای حذف مواد آلاینده خاک و ترکیبات نفتی دست یافته ایم. این مقاله مزایا و معایب فرایتد را ارزیابی می نماید. بنظر میرسد این تکنولوژی برای تصغیه پساب نفتی و خاک آلوده به مواذ نفتی راه حل مفید و سودمندی را ارائه نموده است.

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