Design of automated oil sludge treatment unit

N Chukhareva[1,2], T Korotchenko[1,3] and A Yurkin[1,4]

[1] National Research Tomsk Polytechnic University, 30 Lenin Ave., Tomsk, 634050, Russia

E-mail: [2] natasha@tpu.ru, [3] tatyana1003@mail.ru, [4] yurkin0660@mail.ru

Abstract. The article provides the feasibility study of contemporary oil sludge treatment methods. The basic parameters of a new resource-efficient oil sludge treatment unit that allows extracting as much oil as possible and disposing other components in efficient way have been outlined. Based on the calculation results, it has been revealed that in order to reduce the cost of the treatment unit and the expenses related to sludge disposal, it is essential to apply various combinations of the existing treatment methods.

1. Introduction

The continued progress of oil industry advances the application of resource-efficient technologies based on technical, economic, and environmental principles. The violation of the above principles generally causes the loss of irreplaceable natural resources and, as a result, environmental damage. Therefore, the international ecological standards ISO 14000 aim to persuade companies to take more responsibility for violation of these principles and regulations [1]. However, financial costs annually incurred by petroleum companies because of oil and gas transportation accidents do not decline [2]. This obviously necessitates improvements in the existing technologies and prompts development of new ones which would be effective in oil spill detection, elimination, and further treatment of oil sludge.

The annual volume of spilled hydrocarbons to be utilized urges to develop efficient, reasonably priced, and environmentally friendly technologies based on the various physical and chemical methods of separation. In addition, treatment of oil sludge has been one of the most important aspects of environmental protection in petroleum industry [3].

2. Materials and methods

Today, there are both foreign and Russian companies which are focused on oil spill elimination and further utilization and treatment of oil and oil sludge. The literature review reveals the most widely applied technologies which have been developed both by Russian (LLC «Avantage», LLC "Spetzautocom", ZAO "RusEcoProject") and foreign companies (LLC «Alfa Laval», AG «MOG») [4-6].

The oil sludge treatment unit produced by Swedish company «Alfa Laval» has been chosen as one of the most successful decisions in terms of operational parameters and cost efficiency. Its basic parameters are listed in table 1. All calculations were made per one month of machine operation given that it was a five-day working week and 8-hour work day. The calculations involved the current price for oil sludge treatment (1250 rub/m^3).

Table 1. Technical characteristics of *"Alfa Laval"* oil sludge treatment unit.

Company	**Power**	**Price**	**Treatment capacity**	**Treatment methods**
LLC «Alfa Laval»	45 kW	13 000 000	9 m^3/h	Physical, chemical, biological
Price of a block	**Operational cost (mains)**	**Operational cost (on-site)**	**Total profit**	**Payback period**
	36 956		1 800 000	7.2 months

The advantages of Swedish project are as follows: high treatment quality of any oil products, compliance with modern environmental standards, high reliability and technical support guaranteed by the manufacturer. However, the discussed oil sludge treatment unit has the following limitations: impossibility to regenerate the initial state of spilled oil or petroleum product and need for consumables (filter cartridges and chemical reagents).

3. Results and discussion

Having considered all the advantages and limitations of "Alfa Laval" project, the authors have made an attempt to develop a new facility within import substitution framework with due regard to the listed characteristic features.

Based on the calculations which involve the costs related to the proposed unit operated from different power sources, it has been revealed that one of the most effective methods to cut sludge treatment cost is the possibility to carry out all works stationary. Depending on the operating conditions, autonomous field work will be 3-4 times more expensive (table 2).

Table 2. Technical characteristics of the proposed treatment unit.

Company	**Power**	**Price**	**Treatment capacity**	**Treatment methods**
proposed unit	15 kW	1 745 200	2 m^3/h	Physical methods
Price of a block	**Operational cost (mains)**	**Operational cost (on-site)**	**Total profit**	**Payback period**
300 000	12 318.75	47 232	400 000	4.4 months

Another main feature of the proposed oil sludge treatment unit is the possibility to apply physical treatment methods. Unlike biological and chemical methods, physical treatment method allows achieving the required quality level of the treated sludge as its structure remains constant [7-11]. Therefore, it can be stated that the new treatment unit is resource efficient and it allows the second use of oil sludge and its further utilization (for example, for road pavement or building materials production, etc.)

It should be noted that the change of the Russian Federation towards industry development implies application of domestic details and components because of financial benefits. As a result, the project cost at the stage of facility assembly, as well as the cost of the final product could be significantly reduced with the little changes in quality level as opposed to Swedish and British analogues.

At the same time, the possibility to combine several treatment methods is also considered. This would contribute to the competitiveness of the proposed unit as the possibility to apply several treatment methods could significantly expand areas of usage. To be more precise, such a sludge treatment unit can be applied when the treatment capacity is more important than preservation of oil initial characteristics. As it is stated in [8,12], when it is impossible to preserve the initial characteristics of spilled oil, it is more reasonable in terms of financial losses and treatment capacity (m^3/h) to apply biological treatment method. In addition, this method should be considered when there is higher risk of expanding the contaminated area. The main advantage of bioremediation is that it

allows treating large volumes of oil sludge within a relatively short period in comparison with physical treatment methods. However, it is worth noting that biological method also has a number of shortcomings: difficulty in regenerating oil characteristics, limitations related to environmental conditions such as temperature, moisture, pH, and contaminant composition.

Thus, the combination of several oil sludge treatment methods would make the proposed oil sludge treatment unit more multi-applied, which in its turn, means that it could be used in solving various engineering tasks.

It should be noted that the change of the Russian Federation towards industry development implies application of domestic details and components because of financial benefits. As a result, the project cost at the stage of treatment unit assembly, as well as the cost of the final product could be significantly reduced with the little changes in quality as opposed to Swedish and British analogues.

To verify the advantages of the new oil sludge treatment unit, the comparison of the proposed treatment unit and Swedish one, as well as, the feasibility study in terms of short-term perspective (3 years) and long-term perspective (10 years) has been carried out. The calculations have been made for physical treatment methods only. The cost of one cubic meter of the sludge was 500 rubles. Among other possible expenses, energy consumption and price of purchased equipment were considered. Unlike "Alfa Laval" facility, the proposed treatment unit has obvious advantages in terms of short-term perspective. This is explained by lower price of domestic assembly components used in new treatment unit. However, long-term perspective does not evidence any significant difference in profits (table 3).

Table 3. Profit and work volume comparison for short- and long- term perspectives.

Parameters	**Alfa laval (1 unit)**	**Proposed treatment unit (4 units)**
Processing capacity (m^3/hour)	9	8
Expenses (unit assembly and energy, 3 years)	14 304 160 rubles	8 754 700 rubles
Total profit (3 years)	25 920 000 rubles	23 040 000 rubles
Volume of treated sludge (3 years)	51 840 m^3	46 080 m^3
Expenses (unit assembly and energy consumption, 10 years)	17 434 750 rubles	12 893 800 rubles
Total profit (10 years)	86 400 000 rubles	76 800 000 rubles
Volume of treated sludge (10 years)	172 800 m^3	153 600 m^3

In addition, it should be noted that in searching for new solutions in oil sludge treatment the main task was to develop not a huge stationary facility, but a compact mobile treatment unit. It means that the feasibility study for short-term perspective should be more accurate under planned operation conditions.

4. Conclusion

The most significant findings to emerge from this study are as follows:

- the proposed oil sludge treatment unit is of low cost in comparison with European analogues;
- due to high mobility, insensitivity to the sludge composition, small number of staff required to operate the unit, it is possible to provide more cost-effective in-situ oil spill response as compared with the ex-situ methods;
- having a proper financing, the further development and serial production of the proposed unit will provide qualified specialists with new workplaces and contribute to dealing with small local spills far from big refineries;
- the proposed treatment capacity is enough to treat oil sludge of a small refinery.

References

[1] Russian Business Consulting (RBC) [Electronic resource]: Russian Business Consulting. Electronic journal, 2000. URL:http://t.rbc.ru/tyumen_freenews/19/11/2014/956527.shtml (reference date 27.01.15)
[2] Independent Newspaper [Nezavisimaya gazeta] 2000 [Electronic resource]: URL: http://www.ng.ru/ng_energiya/2014-12-09/11_vred.html (reference date 27.01.15).
[3] Li H, Song S F, Qu C T, Xie Q and Yang B 2013 Study of treatment process and development of oily sludge *Advanced Materials Research* **838-841** 2667–72
[4] Storm-15 Machine [Electronic resource]: official web site "Man oil group". URL: http://www.manoilgroup.com/media/storm-15-ru.pdf (reference date 17.09.14).
[5] Patent 94012433 Russian Federation, Int. Cl. H 04 B 1/38, H 04 J 13/00 Method for Treatment of Oil Sludge and Soil Decontamination / Zorkin V A, Bushueva N N, Pobedinskiy N A, Beznosov V N, Chevardova N P, Aisin E Kh, Moiseev P A and Chalchenko V P Proprietors: Zorkin V A, Bushueva N N, Pobedinskiy N A, Beznosov V N, Chevardova N P, Aisin E Kh, Moiseev P A and Chalchenko V P № 94012433/26; date of filing. 08.04.94; date of publication 20.08.96, Bull. № 36 (Part II) p 3
[6] Patent 2434051 Russian Federation, Int. Cl. H 04 B 1/38, H 04 J 13/00 Mobile Module Unit for Utilization of Oil-Slime and Rejects of Products of Oil and Gas Processing / Il'in R J, Luk'janov A S, Seregin S N, Zakhar'ev G G, Magzanov S I and Sidorenko V N Proprietors: ZAO "Rusehkoproekt" (RU) № 2000131736/09; date of filing 11.06.10; date of publication 20.11.11, Bull. № 32 (Part II) 3 p.
[7] Pleshakova E V 2010 *Ekologo-funktsional'nye aspekty mikrobnoy remediatsii neftezagryaznennykh pochv* (Saratov: Saratov State University) p 47
[8] JSOC Bashneft [Electronic resource]: official web site, Alfa-laval oil sludge treatment unit maintenance. URL: http://zakupki.bashneft.ru/purchase/11028/ (reference date 24.10.14).
[9] Kaminsky E F and Khavkin V A 2001 *Glubokaya pererabotka nefti: tekhnologicheskiy i ekologicheskiy aspekty* (Moscow: Technics) p 383
[10] Pikovsky Y.I. 2003 Problema diagnostiki i normirovaniya zagryazneniya pochv neft'yu i nefteproduktami *Pochvovedenie* **9** p 1132–40
[11] Khavizov A R 1996 *Utilizatsiya otrabotannykh masel* (Ufa: Reaktiv) p 260
[12] Akhmetov S A, Ishmiyarov M Kh and Kaufman A A 2009 *Tekhnologiya pererabotki nefti, gaza i tverdykh goryuchikh iskopaemykh (*Saint-Petersburg: Nedra) p 827