Use of oil sludge as a combustible additive for the production of bricks

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Abstract. The impact of extractive industry facilities on the environment is manifested both at the construction stage and at the stage of their exploitation, and even after the exhaustion of natural resources. The relevance of this problem is becoming much higher for the oil and gas industry, where the processing and reclamation of drilling waste are of the highest importance. This makes it necessary to study possible ways of processing and obtaining useful components for the industry. We considered the most hazardous pollutant of almost all components of the natural environment of the oil and gas industry - oil sludge. We studied the possibility of its use as a secondary material resource, namely, as a combustible additive in the production of bricks to minimize anthropogenic environmental impact.

1. Introduction

The production activities of oil and gas production and oil refining enterprises have an anthropogenic impact on the environment [1]. The development of oil fields is associated with the formation of a significant amount of oil-contaminated waste. It includes fuel and oily wastes, cutting fluids, oil sludge and sediments, as well as waste from petrochemical enterprises (acid tar and bitumen) [2]. One of the most hazardous pollutants of almost all components of the natural environment - surface and ground waters, soil and vegetation cover, atmospheric air - is oil-containing waste, oil sludge [1].

In Russia, more than 3 million tons of oil sludge is generated annually. Oil production companies account for more than 1 million tons of oil sludge and oil-contaminated soils; oil refineries - 0.7 million tons; tank farms - 0.3 million tons; other sources (railway transport, airports, seaports) - 0.5 million tons. In general, the volume of oil waste generation in the world reaches 10 billion tons. There are 7 kg of oil sludge per ton of refined oil, which leads to a large accumulation of the former in earthen containers of oil refineries.

Disposal of oil sludge is a complex problem for all oil companies, primarily because of its scale. Over the past decades, waste volumes at oil production and transportation sites have reached hundreds of thousands of tons. The processing of oil sludge is a rather difficult task and most of the methods used for its processing often do not justify themselves for some reason [3].

A separate problem is the numerous sludge pits, the “ecological scourge” of each deposit. The lack of specialized waste landfills and the lack of effective equipment for oil sludge processing until recently forced enterprises to store it on their territory and, accordingly, pay for negative environmental impacts [4].
Storage of oil sludge causes complex environmental problems, while at the same time, the oil part of it is a valuable organic raw material. As a result of its disposal, it is possible to obtain commodity products such as hydrocarbon gas, commercial fuel components, lubricants, bitumen, and others, as well as disposal products - uncultivated soil, ash, soot, and gaseous components [1]. The centralized collection, processing and disposal of existing and newly generated oil sludge at oilfield facilities, and the elimination of oil sludge ponds ensures the improvement of the environment, prevents pollution of surface and ground waters, atmospheric air in the region, and provides for the return of land for industrial and agricultural use [5].

Oil sludge is a complex physico-chemical mixture, which consists of petroleum products, mechanical impurities (clay, metal oxides, sand) and water. The ratio of its constituent elements can be very different. The qualitative characteristics of oil sludge at enterprises fall within the following limits:

1. Organic matter from 10% to 25% of the mass;
2. Mechanical impurities from 5% to 30% of the mass;
3. Water from 50% to 70% of the mass [1].

In sludge collectors, this mixture is stratified, forming three layers:

1. The bottom layer, or bottom sediment, consisting of 70% of the solid phase, impregnated with petroleum products (up to 5-10%) and water (up to 25%);
2. The middle layer consisting of water contaminated with petroleum products and suspended solids;
3. The top layer consisting of an emulsified layer of petroleum products, containing mainly up to 5% of mechanical impurities.

The composition of oil sludge depends not only on the origin of the latter, but also on the duration of its storage.

The need for disposal of oil sludge is due to several reasons:

1. It leads to pollution of the lithosphere, air and water basins and poses a threat to public health;
2. Sludge collectors are also dangerous in terms of fires;
3. Pits occupy large areas, and due to their shortage, oil wastes are often burned without purification of exhaust gases;
4. Waste contains valuable hydrocarbon raw materials [6].

Depending on the composition and physico-chemical properties of oil sludge, various technological schemes are used for its disposal. When choosing a technology, a company takes into account its financial affordability, as well as expediency for the consumer. For a specific industry, the necessary technology can be implemented, taking into account both economically and technically affordable conditions. An important aspect in the disposal of waste in petrochemical enterprises is integrated environmental protection, i.e. no more pollution should occur when applying a technology of waste neutralization.

The priority direction for waste management is its use as secondary material resources. This allows not only reducing the environmental burden, but also ensuring a more rational use of natural resources.

2. Study Objects and Methods

The oil sludge of the Yarakta oil and gas condensate field was selected as the object of research. The Yarakta oil and gas condensate field is geographically located 140 km north-east of the city of Ust-Kut, closer to the northern part of the Ust-Kut Municipality and the southern part of the Katangsky Municipality of the Irkutsk Region of the Russian Federation. The oil and gas potential of the field is primarily associated with sediments of the Vendian and Cambrian ages, namely, sandstones of the Yarakta horizon with a total thickness of up to 40 m. The resource oil reserve is estimated at 102.5 million tons, and its density is 0.830 g/cm³ or 34° API. The density of the condensate is the same as 0.67-0.71 g/cm³. The operator at the Yarakta field is Irkutsk Oil Company LLC, for which it is the main field, since 60% of the company's total raw hydrocarbons are produced here.
We carried out laboratory analyzes of the composition and physico-chemical properties of oil sludge in this field and presented the calculation of economic efficiency from the application of this technology. We also investigated the possibility of using oil sludge as a combustible additive for the production of bricks at the Ust-Kut Brick Factory.

3. Results of Research
The basic principles for choosing the proposed technology for the neutralization and disposal of waste from petrochemical enterprises are as follows:
1. Identifying the composition, quantity and properties of disposed waste, factors affecting their changes;
2. Selecting a technology that causes minimal damage to the environment, has low capital costs, allows making profit;
3. The choice of the application of waste as a secondary material resource depends on the composition of the waste, operational technological and sanitary requirements for raw materials and manufactured products [7].

The use of waste from oil and gas production and oil refining enterprises as a secondary raw material seems to be the main direction in the treatment of oil waste. This will lead to the most efficient use of natural mineral resources and improve the environmental situation. The most developed area for the application of oil sludge is its use in the construction and production of building materials. From literature it is known that the use of industrial waste can cover up to 40% of the needs of the construction industry for raw materials, reduce the cost of manufacturing building materials by 10-30%, compared with their production from natural raw materials. Therefore, to find new ways to use oil sludge as a secondary raw material, it seemed interesting to study the possibility of using it as a component of clay raw materials undergoing heat treatment, i.e. firing.

Clays consisting mainly of kaolinite (Al₂O₃·2SiO₂·2H₂O) are called kaolins. Conventional clays differ in chemical and mineralogical composition from kaolins, since in addition to kaolinite they contain quartz, mica, feldspars, calcite, magnesite and others. The most important properties of clays are: plasticity, behavior to drying (air shrinkage) and behavior to high temperature. Plasticity makes it possible to mold various ceramic products from clay. The degree of plasticity depends on the mineralogical and grain composition, shape and nature of the surface of the grains (rough or smooth), as well as on the content of soluble salts, organic part and water.

Characteristics of oil sludge show that it is necessary to investigate the possibility of using oil sludge as an organic additive, especially since the requirements for clay raw materials in terms of water content and mechanical impurities are not high. In addition, the volume of clay used as a raw material for the production of bricks and keramzit concrete is hundreds of thousands tons per plant, therefore, when 1-3.5% of oil sludge is added as an organic additive, the volume of its use will be from thousands to tens of thousands of tons.

The results of the study on the behavior of oil sludge upon heating indicate its calorific value and allow us to find its application in the construction industry as a component - a combustible additive for bricks and keramzit gravel.

D. Sperber who dealt with this issue in detail in his scientific work [8], studied the influence of the ratio of clay, oil sludge and water contained in oil sludge on the quality of bricks. The results of the study on the quality of the produced bricks are presented in Table 1.

As tests show, the optimum mass ratio of clay : oil sludge is 1: (0.09 - 0.35), the water content in oil sludge is 22-70% by weight. The requirements for oil sludge in the brick production are established based on the tests [8] table 2.

After sampling soil from the sludge collector at the Yarakta oil and gas condensate field in the summer, its composition will be determined. Based on the results of the analyzes, this oil sludge can with great probability be used in the future to produce bricks.
Table 1. Quality of the produced bricks.

| No. | Mass ratio of clay : oil sludge | Water content in the oil sludge, % | Mechanical compressive strength, MPa | Frost resistance, Cycles | Fracturing, % | Average density; Kg/m³ |
|-----|--------------------------------|-----------------------------------|-------------------------------------|-------------------------|--------------|-----------------------|
| 1   | 1 : 0.07                       | 50                                | 42.8                                | 78                      | 3            | 1470                  |
| 2   | 1 : 0.09                       | 22                                | 41.3                                | 94                      | 1            | 1315                  |
| 3   | 1 : 0.14                       | 50                                | 41.2                                | 94                      | 0            | 1300                  |
| 4   | 1 : 0.35                       | 70                                | 41.5                                | 95                      | 1            | 1295                  |
| 5   | 1 : 0.39                       | 50                                | 41                                 | 51                      | 8            | 1380                  |
| 6   | 1 : 0.14                       | 18                                | 21.7                                | 77                      | 5            | 1430                  |
| 7   | 1 : 0.14                       | 75                                | 23.4                                | 49                      | 11           | 1415                  |

Table 2. Requirements for oil sludge in the brick production.

| No. | Indicator                                      | Content, % |
|-----|-----------------------------------------------|------------|
| 1   | Mass fraction of water                        | 22–70      |
| 2   | Mechanical impurities                          | 15–20      |
| 3   | Mass fraction of petroleum products; minimum  | 30         |

4. Discussion

The advantages of this technology for the disposal of industrial waste from the oil and gas industry include:

1. The ability to conduct the brick production process without prior preparation of oil sludge in treatment facilities.
2. It eliminates the need for additional operations to separate the mechanical impurities and water from the organic part.
3. The proposed technology is developed using existing technological equipment. This eliminates additional economic costs for the implementation of the proposed innovations, which is especially important for existing brick factories [8].

Irkutsk Oil Company annually produces an average of 12,200 m³ of oil sludge. The cost of disposal of 1 m³ of oil sludge amounts to 6887 rubles/m³. The cost of transporting 1 m³ of oil sludge to the disposal site amounts to 5987 rubles/m³.

In total, the company needs to spend annually 73 million rubles +84 million rubles = 157 million rubles for the disposal of oil sludge [9-21].

Our proposed technology for the use of oil sludge as a combustible additive for producing bricks was developed using existing technological equipment. This eliminates additional economic costs for the implementation of the proposed innovations, which is especially important for existing brick factories. The city of Ust-Kut has its own brick factory. The annual savings from the disposal of oil sludge will amount to 84 million rubles / year.

Calculation of the economic efficiency of the use of oil sludge in the production of bricks:

The use of oil sludge in the brick production saves clay consumption and reduces the temperature of brick firing, that is, both raw materials and energy are saved. Since oil sludge contains mechanical impurities and organic matter, they are both a thinning and combustible additive, which reduces the bulk density of bricks by an average of 25%.

According to the results of the tests performed by D. Sperber, the optimum is the mass ratio of clay : oil sludge in the range of 1 : (0.09-0.35).

The average consumption of oil sludge is \( \frac{9 + 35}{2} = 22 \% \) by weight.
22 weight % account for 12,200 tons of oil sludge, which is formed per year at Irkutsk Oil Company. Using it one can produce: \[ \frac{100 \cdot 12200}{22} = 55454.5 \text{ tons of bricks,} \]
and save \[ \frac{54454.5 \cdot 25}{100} = 13864 \text{ tons/year of clay raw materials.} \]
The cost of clay raw materials is 576 rubles/ton.

The economic efficiency of saving clay raw materials will be \[ \frac{13864}{576} = 7.985 \text{ million rubles/year.} \]
Thus, the total annual savings from the disposal of oil sludge and saving clay raw materials will be \[ 84 + 7.985 = 91.985 \text{ million rubles/year.} \]

5. Conclusion
Ecological modernization of the principles of waste disposal involves not only the interaction of traditional methods of waste management and measures to reduce its quantity, recycling and disposal, but also monitoring and assessing the environmental safety of waste and disposal products [7]. Based on the calculation and analysis of the data given above, it was found that the storage of waste at temporary storage facilities without subsequent processing is accompanied by long-term emissions, transformations of pollutants and the irretrievable loss of secondary material resources [8]. As a result of the above analysis of oil sludge in the considered field, we revealed its suitability for use as the proposed raw material. From the calculation of the economic efficiency of using oil sludge to obtain a combustible additive in the brick production, it follows that the savings from processing will amount to 91.985 million rubles/year. This will allow the company not only to get rid of hazardous production waste, but also significantly improve the environmental situation in the area in the long term.

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