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Neutralization of Drill Cuttings Discharged into the Environment During the Drilling of Oil Wells

[1]Shirinova D.B, [2]Kazimzade S.M

[1]Associate professor of the department of Petrochemical Technology and Industrial Ecology, Azerbaijan State Oil and Industry University, Baku, Azerbaijan

[2]Postgraduate student in the department of Petrochemical Technology and Industrial Ecology, master's degree in Environmental Ecology and Oil Industry, Azerbaijan State Oil and Industry University, Baku, Azerbaijan

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ABSTRACT

The environmental impact of drill cuttings, which are drilling waste formed during the drilling of oil wells, was studied, and the methods of neutralizing this waste were investigated. The decomposition of drill cuttings with different emulsifiers was compared with the decomposition of drill cuttings with gas welding waste. The decomposition of drill cuttings with gas welding waste at different temperatures and the dependence of product yield on temperature were studied. The effect of different emulsifiers on the product yield and the yield of products obtained from the decomposition of different emulsifiers at the same temperature and at the same mixing time were compared. As an emulsifier, the comparison of gas welding waste with other emulsifiers showed that gas welding waste is as strong and effective as $Ca(OH)_2$ and CaO:surfactant, and the obtained sediment has more strength, which expands the field of use of this sediment. The dependence of drill cuttings decomposition on temperature and mixing speed was studied. It was determined that at a temperature of 90°C and a mixing speed of 100 rpm, 97-98% yield can be obtained during 24 hours of storage. It has been defined that the decomposition of the drill cuttings with this emulsifier is appropriate both from an economic and ecological point of view.

Keywords: Oil, Drilling, Well, Drill Cuttigs, Emulsifier

Introduction

In our modern life, environmental protection is one of the most acute issues of socio-economic problems and is of interest to every person in this and other forms. People process and use natural resources with various technological means to meet their life requirements. In many cases, the intermediate or final product obtained in such processes pollutes the environment as it is useless waste.

Living and non-living nature is changing faster than humans can regenerate it through evolution. An example of this is the rate of formation of oil and gas [1-3].

Reducing the danger of waste is one of the urgent problems in ensuring environmental safety. Drill cuttings, which are rich in rock particles in the form of suspended particles in the drilling mud, are one of the such waste. Drill cuttings have significant negative impact on both the environment and human health. Oil hydrocarbons, toxic components of the drilling mud and heavy metals play a key role in the evaluation of the toxicity of the drill cuttings. Due to its toxic content, drilli cuttings have complex negative impact on the environment and human health. [4-7].

The main toxic agent in drill cutting is oil and its fractions mixed with crude oil during drilling. According to International Standards, the amount of oil in waste drill cuttings should not exceed 100 g/kg. Drill cuttings contains all the chemicals used in the production of drilling mud along with the excavated rocks and oil. The amount of clay in the drill cuttings is 30-90%, the amount of thickeners is 10-30% [8-10].

Drill cuttings belong to the 4th class according to the degree of danger, and its processing requires complex measures. Utilization and burial of drill cuttings by the method used in the 90s of the last century (discharge of untreated cuttings into the sea, burial of untreated cuttings in earthen reservoirs) led to long-term instability of the ecological situation in many oil extraction areas. Therefore, various methods are developed for the safe and practical use or utilization of drill cuttings. The chemical and mineralogical composition of drill cuttings depends on both the type of drilling mud and the type of rock being drilled. The granulometric composition depends on both the rock and the type of drilling mud. From the above, it can be seen that there is not and cannot be a single effective method for working with drilling waste.

The thermal method includes technological burning, thermocondensation, pyrolysis and bitumen production. The mechanical method includes storage in special warehouses, centrifugation or other separation, vacuum and pressure filtration. The chemical method includes dilution with reagents, inorganic (liquid glass, clay) and solidification with organic additives (synthetic resins). Addition of special microorganisms to drill cuttings warehouses and landfills in the biological method (biodestruction).

According to the regulation, the processing of drilling cuttings and drilling waste consists of the following stages:

- Separation of liquid phase of waste from solid phase by natural (sedimentation) or physical (centrifugation or other dewatering) method;
- Cleaning in the reservoir;
- Liquid phase pumping;
- Solidification of residues, drilling cuttings and spent solutions;
- Filling the reservoir (pit) with soil.

Cleaning in the reserve pit is carried out by reaction with a coagulant (aluminum or iron sulfate). Prepared coagulant is sprayed on the surface of the reservoir. After settling for 1-2 days, the liquid phase is pumped from the surface of the reservoir by means of suction, and is captured on the surface of the reservoir by a floating structure. Then the liquid phase in the pit is neutralized, the top layer enriched with oil is pumped into the collector. The dewatered residue of the drill cuttings is cemented.

After treatment of drill cuttings and drilling waste, injection into the oil layers is a common technology for utilization of drilling waste. However, the strict requirements of equipment manufacturers for the preparation and injection of drilling fluids also dictate the requirements for raw material inventory and it is not always economically feasible to comply. In addition, drilling is allowed only in certain geological conditions of the oil field. Thermal method of utilizing drill cuttings and drilling fluids is a universal and effective method. Thermal methods of utilization are the most effective due to their versatility. Currently, the commodities market offers a large number of equipment for thermal processing of drill cuttings. It is prospective to use drill cuttings as a raw material for the production of materials used in internal filling of building materials, soil mixtures, field roads and drill sites. Although active research is currently being conducted on the use of drilling waste as building materials, the lack of an efficient processing method limits their industrial application.

The authors conducted research by adding various chemical additives to the drill cuttings and filtering it. It was found that thermally decomposed graphite sorbent is hydrophobic, 1 gram of sorbent has the ability to sorb 40-60 grams of oil and oil products. It is resistant to temperatures of 300^0C in air and 3000^0C in airless conditions, and when using superplasticizer Meflux (superplasticizer based on sodium sulfonaphthalinformaldehyde and sodium sulfomelaminformaldehyde, added to dry construction mixture), the moisture content of the mixture is low, but it is high when the the amount of oil is increasing. When lime is added, the filtering speed increases, and the percent amount of the filtrate decreases [11-13].

It has been determined that when the amount of oil in the drill cuttings increases, its filterability and durability decrease, regardless of the accumulation time. The analysis of the percentage of oil in the drill cuttings showed that the filtration process improves with the increase of oil viscosity. The effect of the amount of oil on the durability of artificial stone obtained by hardening with cement is given in the following figure [14-17].

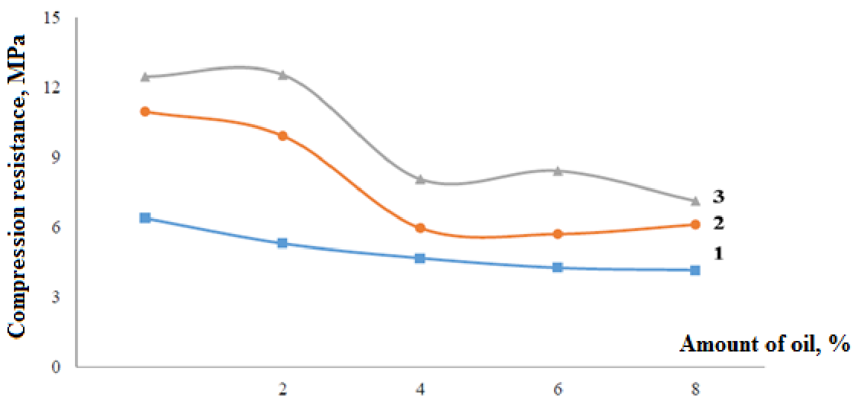

Figure 1. The effect of the amount of oil on the durability of artificial stone hardened by cementation

1.After 1 day; 2. After 7 days; 3. After 28 days.

One of the simpler utilization methods of drill cuttings may be its use as an inert material in a layered toxic or solid waste landfill. To reduce the toxicity of drill cuttings, it can be mixed with peat or soil. The authors investigated the use of drill cuttings as a biostimulant for plant growth. For the experiment, they prepared a model mixture with the following composition (Table 1).

Table 1. Composition of the model mixture

№	Components	Amount, mass %
1	Bentonite clay	2
2	Sodium carbonate	0.5
3	KCl	0.5
4	Na2SO4	0.5
5	CMC (carboxymethylcellulose)	0.3
6	FCLS (ferrochrome lignosulfonate)	0.5
7	Water	the rest

The mixtures prepared for the sample were added to the soil in the ratio of 0.5%, 1.0%, 3.5% by mass. The experiments were carried out on clay and sandy soil. Lepidium sativum was used as the test object. Efficiency was evaluated by seed germination andseedling length according to the known method. As a result of the study of seedling germination and length, it was found that the optimal concentration of the model mixture to stimulate plant growth is 0.5% for all types of soil studied.

The obtained results made it possible to continue research with drilling waste with a total mineralization of 5-6 g/l. The results of the experiment confirmed the role of biostimulation of the waste (drill cuttings) at a concentration of 0.3-0.5% in the growth of the Lepidium sativum.

Thus, drilling waste can be used as a mineral fertilizer to stimulate the growth of plants, especially during renovating of industrial enterprises within the limits of the sanitary protection zone, as well as the organization of the roadside zone outside residential areas [18-21].

Materials and Methods

It is known that in the oil and gas industry, 8-10% of the oil produced in the form of slurry during the drilling of wells and the same percent of the oil processed in oil separation processes are discharged into the pits in the form of a continuous emulsion, causing environmental stress equal to the loss of raw materials. The composition of this slurry consists of 45-48% oil, 1-2% salts, and the rest is water. Various inorganic compounds are used to separate the oil fraction from this emulsion. Some emulsifiers with different compositions have been mentioned in various literatures. Based on these studies, using different emulsifiers, the effect of their composition on the products obtained from the decomposition of the drill cuttings was studied.

The research was carried out by taking the ratio of 50 grams of crude oil, 10 grams of sand, and 40 grams of water in the modeled slurry composition. For the experiment, emulsifiers such as pine wood chips (sawdust), KaOH, NaOH, CaO and surfactant (detergent), $Ca(OH)_2$, gas welding waste were used. These experiments were carried out at different temperatures, different mixing speed, and different time of storage of the mixture. The conditions of the experiments are given in the following tables. It has been found that calcium oxide and calcium hydroxide are the most effective demulsifiers, because the yield of oil is high, the obtained solid waste and water content are not contaminated with dangerous harmful substances.

Research has revealed that after pouring 500 ml of prepared drill cuttings, 80–100 grams of calcium oxide, 100–120 grams of calcium hydroxide, or gas welding waste, this mixture was stirred for 10 minutes at 90-100^{0}C and kept for a day.After keeping the mixture for one day, the drill cuttings were separated into two parts, consisting of the upper part and the lower part. The upper part consists of a pure oil fraction, and the lower part consists of sediment and an aqueous solution of calcium hydroxide. The theoretical yield of oil in this demulsification process is 95-96%. When the split emulsion is stored at room temperature for a week, the yield of oil reaches 97-98%.

Our experiments have shown that calcium hydroxide (first containing 3-5% $Mg(OH)_2$), which is a waste of the gas welding process (then $Ca(OH)_2$), is fully suitable for this purpose. Economically and ecologically, it is more convenient to use compared to others. As a result of the research, it can be noted that the utilization of both waste is very relevant, both in terms of reducing environmental stress and raw materials.

Table 2. Decomposition of drill cuttings using different emulsifiers

№	Emulsifier	Duration of experiment, hours	Temperature, °C	Yield (%)		
				Oil	Water	Sediment
1	KOH	24	90	46	24	26
2	NaOH	24	90	46	24	26
3	Tree bark	24	90	35	25	25
4	Ca(OH)2	24	90	48	27	25
5	Gas welding waste	24	90	47.5	24.8	27.7
6	CaO:surfactant (92-93% :7-8%)	24	90	47.8	26.5	25.5

It seems from our research that at temperatures below 40–50 °C, the hydration process increases. 90 grams of Ca(OH)2 were added to 500 ml of oil slurry. The experiments were performed at mixing speeds of 100 and 150 rpm. When mixing at 100 rpm, mixing (softening) was completed in 20 minutes, while mixing at 150 rpm, softening (mixing) was completed at 100 °C in 10 minutes. However, using much energy in this process is a negative side of the process.

Table 3. Drill cuttings decomposition under the influence of $Ca(OH)_2$ at different temperatures

№	Emulsifier	Duration of experiment, hours	Temperature,°C	Yield (%)
1	$Ca(OH)_2$	24	40	34
2	$Ca(OH)_2$	24	60	63
3	$Ca(OH)_2$	24	80	84
4	$Ca(OH)_2$	24	90	97-98

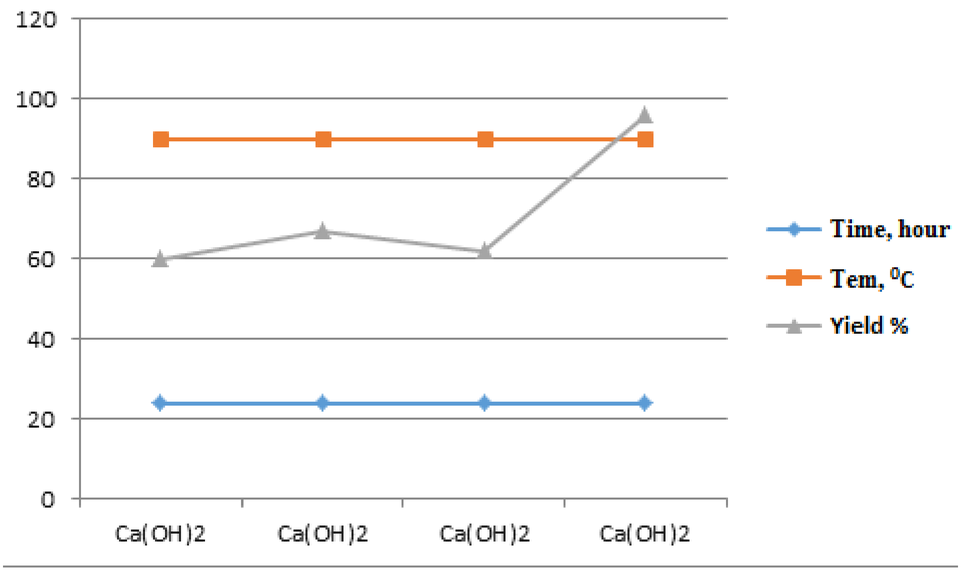

Figure 2. Dependence of product yield on temperature

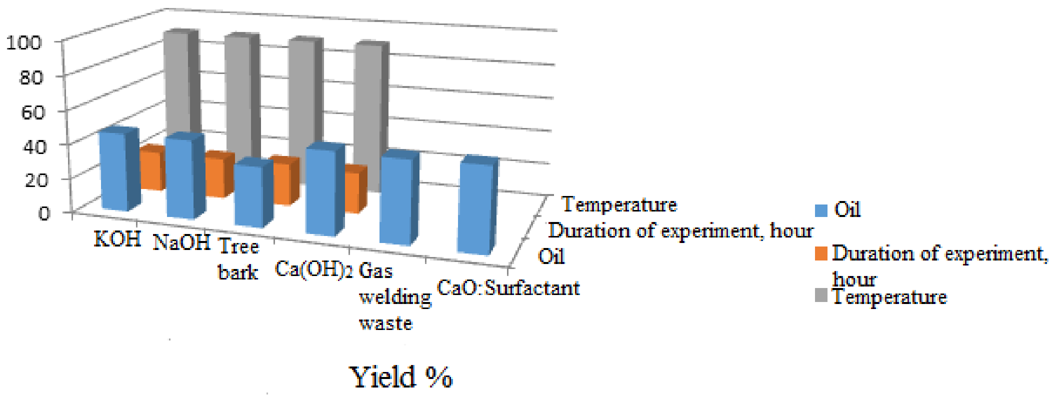

Figure 3. Effect of different emulsifiers on product yield

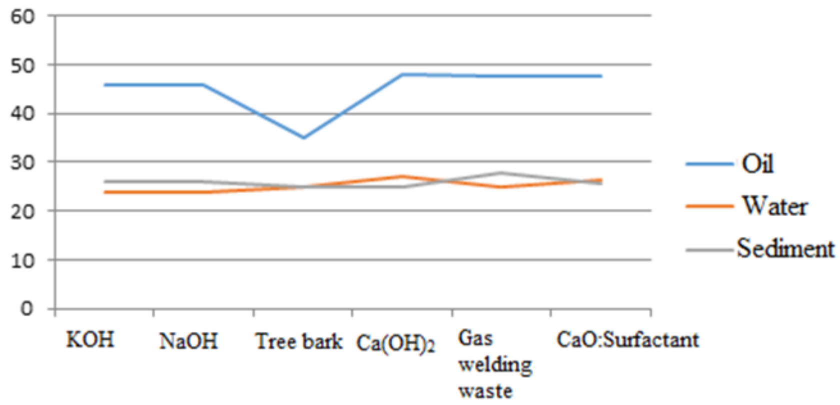

Figure 4. The yield of products obtained from the decomposition of different emulsifiers at the same temperature and the same mixing time, %.

Result

Drilling cuttings are a type of hazardous waste, and its utilization is one of the global issues facing the worl in recent years. There are a number of methods and technologies for neutralization of drill cuttings. It is possible to carry out the process of neutralization and processing drill cuttings using various methods. Decomposition of drill cuttings with gas welding waste and various emulsifiers is one of the neutralization methods, and various studies have been conducted on this method. From the conducted experiments, it was found that the gas welding waste is as effective and strong as $Ca(OH)_2$ and CaO:surfactant, and the sediment obtained from the process is solid and stonger, which expands the field of use of this sediment in the construction materials industry. It was defined that a 97-98% yield can be obtained after 24 hours of storage at a temperature of 90^0C and a mixing speed of 100 rpm. Conducted experiments give us results that decomposition of drill cuttings with this emulsifier is a relevant method that is broadly used.

Conclusion

As a type of hazardous waste, drilling cuttings has many harmful effects. A number of components, heavy metals, hydrocarbons contained in the drill cuttings play an important role in the evaluation of its harmful effect on the environment. Neutralization methods of drill cuttings have been identified to reduce its harmful impact on the environment. During the application of neutralization methods, decomposition processes were carried out with various emulsifiers and gas welding waste. As a result of the comparison of these processes, it was found that gas welding waste has strong effect as Ca(OH)2 and CaO:surfactant emulsifiers and decomposition process with this emulsifier results formation of stronger sedimente. This, in turn, expands the use of sediment for building materials in construction and other fields of industry. As a result of the conducted studies, it was determined that it is possible to obtain 97-98% yield under certain conditions in the decomposition process. So, because it is an effictive method from the economic and ecological point of view the decomposition of drill cuttings with this emulsifier is widely carried out.

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