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Effect of different filtration materials on oil and water separation efficiency

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Abstract. The key to remove oily wastewater by coarse graining is the selection of filtration materials. In this paper, the four kinds of filtration materials were tested the efficiency of oil and water separation, which are walnut shell, ceramsite, oil sand and polyethylene. The results of laboratory experiments showed that walnut shell and oil sands as oil-soluble media had higher separation efficiency. With the increase of sewage flow velocity, the separation efficiency of porous media decreases. With the increase of the thickness of the porous medium, the separation efficiency increases, and the separation efficiency can reach 100% when the thickness reaches a certain value.

1. Introduction

In China, most of the oil field has entered the middle and late stages of oil development, the amount of water that needs to be injected into the reservoir increases year by year, so the amount of sewage produced also increases [1-3]. Oil-water separation produces a large number of oily wastewater that can cause pollution to the environment hazards if it is not disposed of directly. It will ultimately threaten the lives of people and cause economic losses. The primary treatment of oily wastewater by using the filtration material can greatly reduce the oil content, and then a two stage treatment and advanced treatment can make the sewage indicators reach the quality requirements of the reinjection water [4-5]. In this paper, the filtering materials are selected for on-site wastewater treatment through the use of indoor experiment. The filter material can make small oil droplets coalesce into large beads and easy gravity separation, so as to improve the processing efficiency [6-7].

2. Experimental condition

2.1. Physicochemical properties of oily wastewater

Oilfield wastewater is usually oil-in-water dispersion system. Oil in oil wastewater is mainly present in four states which were free oil, dispersed oil, emulsified oil and dissolved oil, the results shown in Table 1.

Table 1. Oil status in oily waste water.

Status	Particle size	Stability	Removal method
Free oil	>100μm	Instable	Gravity separation
Dispersed oil	25~100μm	Instable	
Emulsified oil	0.1~25μm	Stable	Filtering material
Dissolved oil	<0.1μm	Extremely stable	Chemical method

The data in the table show that the stability of free oil and dispersed oil is poor and crude oil can be removed by using gravity degreasing facilities. The dissolved oil particle size is very small which needs to be removed by chemical methods.

In this paper, emulsified oil with particle size between 0.1 and 25μm was used as the object of study which is made by using the screw pump mixing white oil and water in accordance with the ratio of 1: 9 mass ratio. The average droplet size of the oil droplets in the three parallel experiments was 18.4, 17.8 and 17.5μm, which satisfied the experimental requirement. The oily wastewater obtained in the experiment is shown in Figure 1.

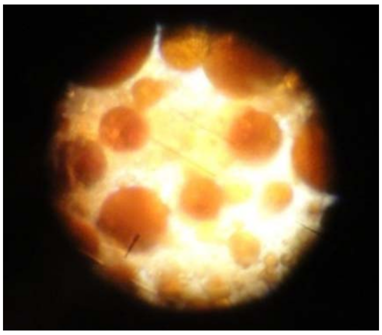


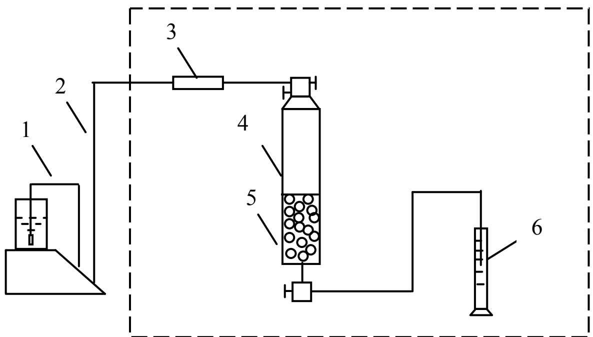
Figure 1. Oil droplets in sewage.

2.2. Oil-water separation device and filtration materials

- Experimental equipment: advection pump, sand filling tube, test tube;
- Filtration materials: walnut shell, ceramsite, polyethylene, oil sand;
- Experimental temperature: room temperature.

2.3. Experimental procedure and parameters

First of all, t is loaded into the sand filled pipe to the specified thickness, and then the oil-water mixture is filled above the filter material. The displacement of simulated wastewater to the material adsorption saturation at a speed of 2.44×10^{-4}m/s. Displacement of sewage into the adsorbed saturated media at different speeds, the amount of injected water and the oil content at the outlet end were calculated. 10% of the injected water quality is defined as the amount of oil entering and the cumulative oil level at the outlet end is defined as the oil output. Separation efficiency can be calculated. The experimental procedure is shown in Figure 2.



1. Advection pump;
2. Pipeline;
3. Flowmeter;
4. Sand filling pipe;
5. Filter material;
6. Burette.

Figure 2. Experimental setup.

3. Experimental results and analysis

3.1. Seepage capacity of sewage in different filtration materials

The suction force of the oil droplets in the porous media formed by the filter material is equal to the seepage resistance. According to Darcy's formula:

$$Q = \frac{kA\Delta p}{\mu L} \tag{1}$$

The formula is deformed to:

$$\frac{\Delta p}{L} = \frac{Q\mu}{KA} \tag{2}$$

The inner diameter of the sand filling pipe is 3.148cm and the length is 6.884cm, the pressure gradient can be calculated as shown in Table 2.

Table 2. Pressure gradients of different filtration materials at different velocities.

T(s)	V(10^{-4}m/s)	ΔP/L(MPa/m)			
		walnut shell	ceramsite	polyethylene	oil sand
50	4.88	0.00359065	0.009245321	0.002273043	0.010111547
100	2.44	0.001795325	0.004622661	0.001136521	0.005055774
200	1.22	0.000897662	0.00231133	0.000568261	0.002527887
500	0.488	0.000359065	0.000924532	0.000227304	0.001011155

When the fluid and porous media are determined, the flow rate, viscosity, and cross-sectional area are all known, and the pressure gradient is inversely proportional to the permeability. The particle diameters of the four kinds of filtration materials from large to small order are polyethylene, walnuts, pro oil sands and ceramsite. The porous media with large particle diameter has large permeability and less resistance under the same velocity condition, so the pressure gradient is smaller. The porous medium with smaller particle diameter is just opposite.

3.2. Separation efficiency of sewage in different filtration materials

The oil and water separation efficiency of four kinds of filtration materials with the thickness of 1cm are shown in Figure 3.

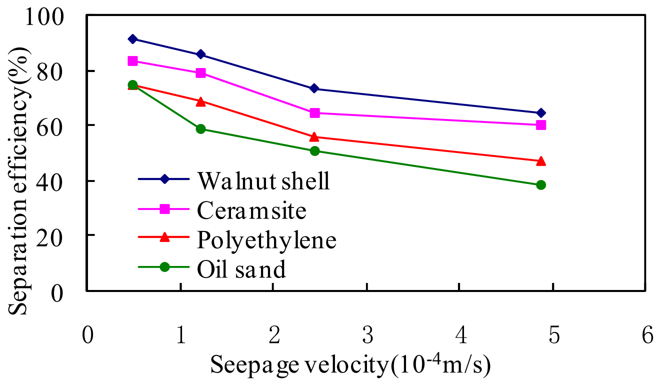


Figure 3. Separation efficiency of different filtration materials.

Under the same flow rate, the separation efficiency of walnut shell was significantly higher than the other three kinds of filter media, the separation efficiency of ceramsite was the second, and the separation efficiency of polyethylene and sand was the lowest. This is because the lipophilic of the walnut shell is the strongest, the adsorption of oil droplets in the water so that the adhesion of oil beads coalescence, from small oil beads into large oil beads, thus increasing the separation efficiency. When the sewage flows through the channel, it increases the collision chance between the oil beads. On the other hand, the oil bead is squeezed and deformed to release the oil film, which improves the separation efficiency. The oil-wettability of polyethylene and sand is poor and the separation efficiency is low.

At this time, the thickness of filter material is low, the short residence time of oil droplets in the filter media leads to a certain amount of oil droplets which have no chance to contact with the pore wall. The coalescence of the ceramisite is weaker than that of the walnut shell. Its coalescence principle is mainly collision and squeezing, forming many curved channels. It is necessary to increase the thickness of the filter material to conduct experiments. The separation efficiency of different thickness of the same media is shown in Table 3.

Table 3. Separation efficiency of walnut shell with different thickness.

V(10^{-4}m/s)	Separation efficiency		
	H=1cm	H=2cm	H=3cm
0.488	91.3	100	100
1.22	85.9	89.7	100
2.44	73.7	82.5	94.7
4.88	64.9	78	86.8

As can be seen from the figure, with the increase in the thickness of the filter material, the separation efficiency is also increased. This is because the increase in the thickness of the filter material to extend the oil droplets and filter media and pipe wall contact time, which is more conducive to floating up the oil droplets and increase the amount of oil. Walnut shell filter thickness of up to 3cm, the walnut shell as a filter material in different sewage flow separation efficiency of 100%. At this time, the oil output is 0ml, into the amount of oil is equal to floating oil. So the increase in the thickness of filter media is conducive to the oil droplets in the full contact with the filter, thereby enhancing the separation efficiency.

4. Conclusion

Through the experiment of sand-filling pipe, the separation efficiency of oil and water of four kinds of filter materials decreased with the increase of sewage flow rate. Under the same flow rate, the separation efficiency of walnut shell was significantly higher than the other three kinds of filter media. With the increase in the thickness of the filter material, the separation efficiency is also increased. When the thickness of walnut shell is up to 3cm, the separation efficiency can reach to 100%.

Acknowledgments

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