Study of the Treatment of Oily Sludge by Bio-slurry Method

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Abstract: In this manuscript, the bio-slurry method was used to treat oily sludge. Four strains of bacillus were selected in the laboratory to biodegrade the crude oil in oily sludge. During the reaction, the residual oil rate was measured regularly, and after the reaction, the degraded crude oil was separated into four components. The results showed that JZ-2 and JZ-3 were effective in biodegradation. The crude oil degradation rate was 72.5% and 74.3%, respectively, and the residual oil rate was decreased from 12.55% to below 2%, among which the degradation rate of saturates was the fastest. It is concluded that the biological treatment of oily sludge can achieve great results and has the potential of field application.

1 INTRODUCTION

The quantity of oily sludge in China is large, the pollutant composition is complex, and the treatment is difficult. If it is not handled properly, a large amount of harmful substances will enter the soil and groundwater, causing serious environmental pollution. Oily sludge treatment technology mainly includes physical method, chemical method and biological method, among which biological method is an environmentally friendly and low-cost method (Gao, 2017; Wael, 2013). Bio-slurry reactor is a typical biological treatment technology, which uses hydrocarbon degrading bacteria to treat oil pollutants in oily sludge. By controlling various reaction parameters, it provides the best conditions for the growth of microorganisms, reduces the reaction time and improves the reaction efficiency (Giulio, 2010; Sunita J., 2017; FM, 2004).

In this study, the basic properties of oily sludge samples were determined first, and then the bio-slurry method was used to evaluate the crude oil biodegradability of four strains of Bacillus, seeking an economical and feasible method for the harmless treatment of oily sludge.

2 MATERIALS AND EXPERIMENTAL METHODS

In this study, four strains were screened from the laboratory, all of which were Bacillus (Kishore, 2007). The strains were numbered JZ-1, JZ-2, JZ-3 and JZ-4 respectively. The oily sludge was collected from Xinjiang oilfield. The moisture content, pH value and oil content were measured, and the results are shown in Table 1.

Table 1: Moisture content, pH value and oil content of oily sludge.

Num-ber	Moist-ure conte-nt (%)	Aver-age value (%)	pH value	Aver-age valu-e (%)	Dry base oil cont-ent (%)	Aver-age valu-e (%)
1	8.68		6.43		7.08	
2	8.53	8.64	6.25	6.40	7.29	7.24
3	8.72		6.51		7.34	

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The experimental device of the bio-slurry reactor is shown in Figure 1, which is composed of a constant temperature water bath, a mechanical stirrer, and a beaker. The experimental steps are as follows: ○,1 200 g of dried sludge samples were added into 5 1L beakers, and then adding 400 mL of inorganic salt medium and the prepared bacterial liquid. ○,2The beakers were placed in water baths at a temperature of 45°C and stir with a stirrer at a speed of 250 rpm. ○,3 Plastic films were covered on the beakers to reduce water loss. Distilled water was added to the beakers and water baths regularly to keep the liquid level in the beakers basically unchanged. ○,4 An appropriate amount of slurry was taken out every 7 days to measure their oil contents.

Figure 1: Bio-slurry reactor.

The content and composition of residual petroleum pollutants in the oily sludge after biodegradation are the main indicators for evaluating the effect of the bio-slurry method in the treatment of oily sludge. In this experiment, the gravimetric method was used to determine the total extracted organic (TEO) matter of the oily sludge. Dichloromethane was used as the extraction agent to carry out soxhlet extraction experiment. According to the quality reduction of the sample after extraction, the oil content could be obtained, and then the residual oil rate of oily sludge could be calculated (Firouz, 2015; Apourv, 2018; Douglas O., 2017). The extracted solvent was dried, and then the biodegraded crude oil was separated into four components to characterize the biodegradation effect.

3 RESULTS AND DISCUSSION

After 35 days of biological treatment, the oil content of oily sludge decreased significantly. Figure 2 to figure 6 show the residual oil rates and degradation rates of adding JZ-1, JZ-2, JZ-3, JZ-4 and blank samples of the initial, 7 d, 14 d, 21 d, 28 d and 35 d. It can be seen from the figures that the residual oil rate of each sample has been reduced. Among them, JZ-3 had the highest degradation rate and the lowest residual oil rate, followed by JZ-2 and JZ-1, and JZ-4 had the worst degradation effect, and the blank sample also has a certain degree of degradation.

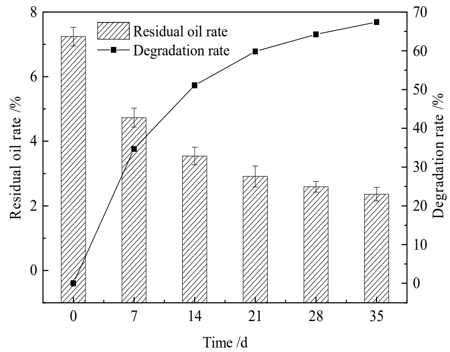

Figure 2: Residual oil rate and degradation rate of sample JZ-1.

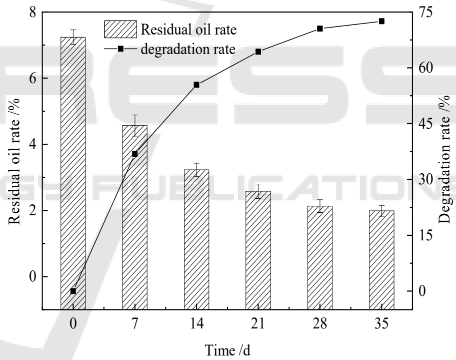

Figure 3: Residual oil rate and degradation rate of sample JZ-2.

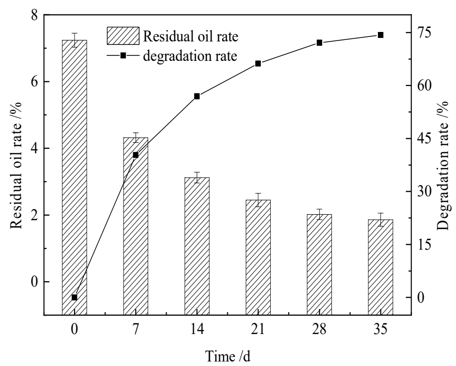

Figure 4: Residual oil rate and degradation rate of sample JZ-3.

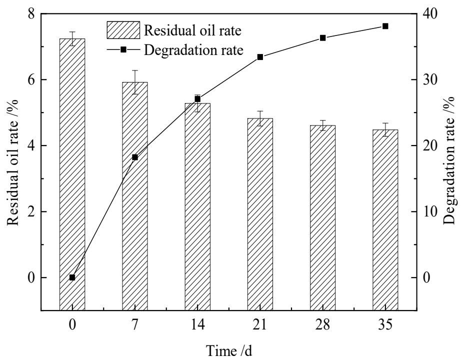

Figure 5: Residual oil rate and degradation rate of sample JZ-4.

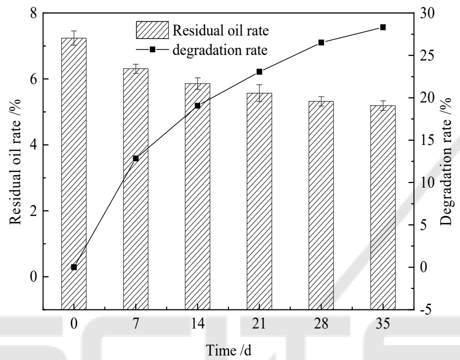

Figure 6: Residual oil rate and degradation rate of blank sample.

It can be seen from Figures 2, 3, and 4 that, the oil content of samples JZ-1, JZ-2 and JZ-3 have been greatly reduced in the first 7 days. The oil was observed, which may have been stripped from the surface of sediment particles by microorganisms. At this time, the degradation rates reached 34.7%, 40.3%, and 36.9%, respectively. The oil content also decreased to a certain extent in the next 14 days, but the oil content changed less at 21-35 days. This may be because the oily sludge contained a large amount of easily degradable organics in the initial stage of treatment. Under this condition, microorganisms could quickly use this part of the organics to grow and reproduce. As time goes by, the content of easy-to-use nutrients decreased, and a large amount of difficult-to-degrade organic matter remained, so the degradation rate slowed down, and the bacterial concentration also decreased.

The device was operated continuously for 35 days, and the residual oil rates of the three sludge samples were reduced to about 2%, which were 2.4%, 1.9% and 1.8%, respectively. The three bacteria had a good effect on the degradation of oily sludge, the degradation rates were 67.4 %, 72.5 % and 74.3 %, respectively. The results indicated that JZ-3 had the best effect, the effect of JZ-2 was not much different from that of JZ-3, and the effect of JZ-1 was relatively poor.

As can be seen from Figure 6, the residual oil rate of blank sample also decreases during the reaction time, which may be that part of the organics in the slurry is volatile, but it is more likely that the oily sludge sample contains hydrocarbon-degrading indigenous microorganisms, which use the residual oil in the slurry to grow, leading to the reduction of residual oil rate. The treatment effect of JZ-4 was better than that of blank sample, and the removal rates of the two sample were 38.1% and 28.3% respectively, but the removal rate of JZ-4 was lower than that of other samples.

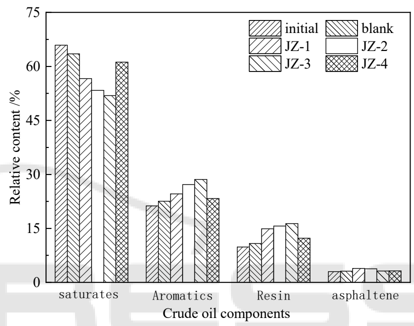

Figure 7: Changes of crude oil components in oily sludge before and after biodegradation.

After 35 days of treatment, crude oil components in all oily sludge samples were separated, and the results are shown in Figure 7. Comparing with the initial sample, the relative contents of saturates in other samples decreased, among which JZ-1, JZ-2 and JZ-3 samples decreased significantly, reaching 9.3%, 12.5% and 14.0%, respectively. The relative contents of aromatics and resin increased, which was equivalent to the changes of saturates in each sample. This is because the saturates is more easily used by microorganisms, so the content change is more obvious compared with other components. However, due to the relatively low content of asphalt, its content does not change significantly.

The content changes of each component in oily sludge are shown in Table 2. After 35 days of biodegradation, the content of four components in each sample decreased compared with the four components in the initial oil sludge, among which the saturates changed most obviously, and the other three components also decreased significantly. Among the samples, JZ-3 had the best biodegradation effect. The degradation rate of saturates reached 79.8%; the degradation rate of aromatics was 65.5%; the degradation rate of resin was 57.35%; the degradation rate of asphalt reached 72.9%. The degradation rates of JZ-2 were 77.7%, 64.9%, 56.3% and 65.3%, respectively. The degradation rates of JZ-1 were 71.0 %, 62.3 %, 50.6 % and 58.0 %, respectively. The degradation rates of JZ-4 were 42.5 %, 32.2 %, 22.7 % and 34.0 %, respectively.

Table 2 SARA analysis results of oil in different sludge samples

Numb-er	Saturate (g/kg oily sludge)	Aromatic (g/kg oily sludge)	Resin (g/kg oily sludge)	Aspha-ltene (g/kg oily sludge)
Initial	47.70	15.40	7.12	2.18
Blank	32.97	11.70	5.62	1.62
JZ-1	13.36	5.80	3.52	0.92
JZ-2	10.62	5.41	3.11	0.76
JZ-3	9.65	5.31	3.04	0.59
JZ-4	27.41	10.45	5.50	1.44

4 CONCLUSIONS

In this study, four strains of Bacillus were used to biodegrade oily sludge by the bio-slurry method. The residual oil rate decreased significantly within the first 7 days of biodegradation. After 35 days of biodegradation, the content of the four components of crude oil in each sample was lower than those in the initial oily sludge, and the saturates had the most obvious change. Among them, JZ-2 and JZ-3 had better effects on crude oil degradation.

The application of biotechnology to the research of oily sludge treatment will play a positive role in promoting safe production and sustainable development of the petroleum industry, creating and maintaining a healthy ecological environment, which has important theoretical and practical significance.

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REFERENCES

ABBASIAN F, LOCKINGTON R, MALLAVARAPU M, et al. A Comprehensive Review of Aliphatic Hydrocarbon Biodegradation by Bacteria [J]. Applied Biochemistry and Biotechnology, 2015, 176(3): 670-699.

DAS K, MUKHERJEE A K. Crude petroleum-oil biodegradation efficiency of Bacillus subtilis and Pseudomonas aeruginosa strains isolated from a petroleum-oil contaminated soil from North-East India [J]. Bioresource Technology, 2007, 98(7): 1339-1345.

GAO H, ZHANG J, LAI H, et al. Degradation of asphaltenes by two Pseudomonas aeruginosa strains and their effects on physicochemical properties of crude oil [J]. International Biodeterioration & Biodegradation, 2017, 122: 12-22.

GHAZALI F M, RAHMAN R N Z A, SALLEH A B, et al. Biodegradation of hydrocarbons in soil by microbial consortium [J]. International Biodeterioration & Biodegradation, 2004, 54(1): 61-67.

ISMAIL W, AL-ROWAIHI I S, AL-HUMAM A A, et al. Characterization of a lipopeptide biosurfactant produced by a crude-oil-emulsifying Bacillus sp. I-15 [J]. International Biodeterioration & Biodegradation, 2013, 84: 168-178.

PANT A, RAI J P N. Bioremediation of chlorpyrifos contaminated soil by two phase bioslurry reactor: Processes evaluation and optimization by Taguchi's design of experimental (DOE) methodology [J]. Ecotoxicology Environmental Safety, 2018, 150: 305-311.

PINO-HERRERA D O, PECHAUD Y, HUGUENOT D, et al. Removal mechanisms in aerobic slurry bioreactors for remediation of soils and sediments polluted with hydrophobic organic compounds: An overview [J]. Journal of Hazardous Materials, 2017, 339: 427-449.

VARJANI S J, UPASANI V N. A new look on factors affecting microbial degradation of petroleum hydrocarbon pollutants [J]. International Biodeterioration & Biodegradation, 2017, 120:71-83.

ZANAROLI G, TORO S D, TODARO D, et al. Characterization of two diesel fuel degrading microbial consortia enriched from a non acclimated, complex source of microorganisms [J]. Microbial Cell Factories, 2010, 9: 13-20.