Research progress in biological treatment technology of oily sludge

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Abstract—Oily sludge is a mixture of the water, the oil and the mud, from oil exploration, transportation, refining process. In this paper, the research status and development of oil sludge biological treatment technology were introduced, including composting method, bioreactor mathod, bioaugmentation process, biological land tillage method, phytoremediation, and so on. All these methods were compared, before the future research suggestion were presented.

Index Terms—Biodegradation; Oily sludge; Bacillus; Oil removal rate; Harmless

1 Introduction

In 2012, China issued the "Twelfth Five-Year Plan" which points out that in the next five years，the state will promote the disposal of oily sludge through technology development and putting the duties of governments at all levels into practice. The oily sludge is a suspended emulsion system composed of oil in water, water in oil , oil and solid residue, which is full emulsification and difficult to naturally subside, mainly including oil separation pond sediment, float sludge and sludge etc. The domestic and foreign scholars research on the oily sludge are mostly concentrated in the technology of the oily sludge harmless treatment, such as extraction method, profile, burning method, curing method, demulsification method, pyrolysis method, chemical cleaning method, the flotation method, and biological method etc. The biological method has the advantages of high efficiency, low energy consumption and simple technique. In this paper, six kinds of biological treatment technology which are more studied recently are introduced, such as land tillage, composting, and flora strengthening method etc. At the same time, some suggestions are proposed for the future development direction of disposing oily sludge by biological treatment, which provide a reference for related research.

2 Research in biological treatment technology of oily sludge

The main mechanism of biological method is the process that the microbe carry out assimilation with petroleum hydrocarbons as carbon source to achieve complete mineralization and transformed into environment friendly inorganic substances such as $C0_2$ and H_2O. Recently more studies have been done.

2.1 Composting method

Composting is mixed oily sludge with appropriate nourishment and stack, then make use of artificial enhanced biological to degrade. Composting can keep microorganisms produce heat during the process of metabolism, which is in favour of the biological degradation of petroleum hydrocarbons in the oily sludge. Dongmei Yu[1] studied a method of disposing oily sludge by composting. They monitored changes of K (the ratio of C / N / P), the content total petroleum hydrocarbon and other parameters in the composting process in 115 days. As a result , the content of total petroleum hydrocarbons droped to 71.7 ± 0.7g/kg from 123 ± 1g/kg by composting. The degradation rate is 42%. It is 215 times as much as non composting treatment. In the twenty-first day, the pile reached to the maximum temperature that was 50 ℃ and K decreased. The hydrocarbon degrading bacteria and aromatic hydrocarbon degrading bacteria in sludge increased nearly 2 orders of magnitude after composting. At the same time, EC50 (biological toxicity characterization value) becomed to 2.76 ± 0.38mg/ml from 1.77 ± 0.128mg/ml. It showed that the biological toxicity has decreased. Shaofu Song[2] studied the effects of bacterial species, inoculation quantity, time of composting and amendment on degreasing rate of biological compost. As a result, the oil removal rate was positive correlated with inoculation quantity and composting time. After 35 days of composting treatment, the oil removal rates of YC-1 bacteria and YC-13 bacteria were 43.41% and 54.02%. The optimal amendments of C-1 bacteria and YC-3 bacteria were soil and soil and buckwheat skin. At present, the oil removal rate could reach 40.01% and 32.55%. Zhao Laiqiang[3] made the improvement to the traditional method of compost and carried out aerobic treatment before anaerobic composting process. As a result, oil removal rate was 97.6%, avoiding secondary pollution. Wang Xinxin[4] analysed the effect of composting method disposing oily sludge with the method of constructing 16SrRNA gene clone library. As a result, after oily sludge was disposed by composting for 90 days, the degradation rate of petroleum hydrocarbon was 53.3% ± 9.5%. Composting treatments increased soil microbial metabolic activity and changed the microbial metabolic characteristics in oily sludge. Fountoulakis[5] handled oily sludge in refinery by composting treatment.and did a group of control test (R1, R2). They regularly monitored the emissions of CO_2 and CH_4 and oil removal rate in R1 and R2. As a result, the emissions of CO_2 and CH_4 were 57.2 mg/kg and 34.3 mg/kg (dry weight) in R1 and R2, where oil removal rate respectively were 52.1% and 62.1%. Wang Xiang etc[6] used biological reactor of pilot scale in the oil field to treat aging oil sludge and monitored the quantity of petroleum hydrocarbon degradation bacteria. As a result, in the end of the test, the number of petroleum hydrocarbon degradation

bacteria was as high as 4.15×107 CFU/g and the biological diversity index was from 1.64-3.02 to 2.83-3.29.

2.2 BIOREACTOR METHOD

Bioreactor is a kind of container, which the oil sludge is added to the nutrition and become slurry. Bioreactor method can reach the purpose of speeding up hydrocarbon biodegradation through operating conditions of artificially controlling temperature, oxygenating, adding nutrient substance and others. Lihui Zhou etc [7] explored oil removing effect of oily sludge by the use of prizing type bioreactor, taking workover oily sludge as the research object and adding petroleum degrading bacteria, nutritive salt, swelling agent. As a result, the oil content was from the original 7.24% to 7.01% after 24 days. Lingyan Zhang etc[8] monitored the change of the lacillus licheniformis amount in bioslurry reactor by using optimized fluorescence in situ hybridization technique including sample fixed time of 17h, buffer solution with deionizing formamide corresponding NaCl concentration of 88 mmol/L, hybrid temperature of 46 ℃, hybrid time of 3 h and deionizing formamide of hybrid liquid concentration of 35%. As a result, oil degradation rate was 35.7%, 28 days later. ZhaoYang Wang[9] reformed the traditional bioreactor and researched the influence of the microbial - electric coupling technology on oil removal rate of oily sludge. As a result, both choosing vertical plug-in electric field(electric field intensity was 3 v/cm)and adopting electric bacteria treatment was more conducive to microbial growth. The oil length of upper oily sludge was from 3.792% to 3.232% and removal rate was 14.79%. The oil length of lower oily sludge was from 4.461% to 0.578% and the removal rate was up to 87.04%.

2.3 BIOFORTIFICATION METHOD

Biofortification method is the method of efficiency petroleum hydrocarbon degradation microbial agent added in oily sludge, in order to achieving the purpose of speeding up petroleum hydrocarbon biodegradation. In that degree of the kinds of microbial agents added, the biofortification method can be divided into single strain strengthening and flora strengthening.

2.3.1 SINGLE STRAIN STRENGTHENING

XiuXia Zhang etc[10] used enrichment culture method to screen and get one strain bacillus HJ-1 with oil from the polluted soil by oil as the only carbon source. They put the fermentation liquid(PH was 7-8, moisture content was 68.51%, the bacteria source add content was 4.4%) of the bacteria in the aerobic fermentation device whose ventilator was 0.2 m3/h. They conducted an experiment .They choosed wood chips and straw as swelling agent, choosing chicken manure as nitrogen source. As a result, oil content droped from 18.77% to 8.87% after 24 days. Oil degradation rate reached 52.7%. RenRen Wu etc[11] got a strain alkane degrading bacteria GS3C in oily sludge and identified it. As a result, this bacterial strain belonged to burkholderia cepacia (homology is 97%). Yeast extract could promote the degradation of n-hexadecane. The main mechanism was that amino acids promoted degradation. QiYou Liu etc[12] put bacteria of microbial flocculant and highly efficient petroleum-degrading bacteria for protoplast fusion, and carried on the research. As a result, the optimal fermentation conditions were that fermentation time was 44 h, inoculum concentration was 1.5%(volume fraction), the initial pH of culture medium was 8.0, medium loading liquid quantity was 30 ml / 250 ml in bottle triangle and incubation temperature is 30 ℃. The oil removal rate of this type strain was obviously higher than the original strain. Nitu Sood etc[13] used Candida digboiensis TERI ASN6 to handle the soil polluted by acid oil sludge. As a result, at low pH condition,the bacteria could efficiently degrade petroleum hydrocarbon, the content of total petroleum hydrocarbons (TPH) in contaminated soil dropped to 7.96 from 184.06 g/kg. Suma etc[14] has separated and purified a kind of bacterial strain ,through the 16SARN technology,identified the bacterium as Bacillus subtilisDSVP23 ,and studied the oil removal characteristics the bacterium. As a result, long chain alkane (C12 - C30) and aromatics in oily sludge were efficiently degraded. Monika Dhote etc[15] from the oily sludge in India separated and purified two strains of bacterias degrading petroleum hydrocarbon (Chry2 and Chry3) and studied their degradation effects. As a result, the oil removal rate were 15.0% and 17.0% respectively.

2.3.2 FLORA STRENGTHENING

YongE Tian[16] through the enrichment and separation method, got a 3 strains of bacteria producing surfactant and 2 strains of oil degradation bacteria. Through the orthogonal test, they got a oil degradation mixed bacteria Flo. 2 that consisted of four strain components. As a result, at the coondition of oil of the initial concentration of 12 g/L, K2HPO43g/L, NaNO34g/L, pH = 8.0, inoculation amount of 7%,oil viscosity reduced by 61.83% and oil degradation rate was 73.19%. when Flo. 2 and inorganic nutrients were added at the same time,oil degradation rate was 71.4% (16 days later). XiaoYan Liu etc[17] from the soil of oil pollution separated microbial flora addicting oil and studied the influences of different factors on the microbial's degradation of oil pollutant. As a result, at the condition of the moisture content of 50%, adding nutrients (N: P = 10) and a moderate amount of H_2O_2, microbial degradation of oil works best. Kaiping Li[18] builded the anaerobic alkane degradation methane-producing system at the condition of taking the oily sludge as inocula,adding C15 - C20 mixed paraffin as carbon source and 37 ℃. From the molecular level he preliminary revealed mechanism of alkane anaerobic degradation methane-producing. As a result, the content of methane in the system increased dramatically and 152 days later maintained at 300 μ mol or so. The methane production of the system was mainly rely on interaction of fermentation bacteria, symbiotic bacteria and acetic acid nutritional type methane-producing bacteria to finish. Gojgic - Cvijovic etc[19] separated and purified efficiently petroleum hydrocarbon degradation bacteria group including pseudomonas, achromobacter sp, bacillus and micromonospra and proceed the degradation test for the oily sludge and the soil polluted by oil, at last the oil removal rate reached 82-88% and 86-91%.

2.4 BIOLOGICAL TO TILLAGE

Biological to tillage also called land farming method that refers to translate the petroleum hydrocarbons of oil sludge into composition of harmless soil by microbial metabolism of the natural environment. Yueming Guan etc[20] disposed sludge whose oil mass fraction were 9.0% and 10.2% with biological to tillage. As a result, iodegradable 120 d later, residual oil mass fraction of sludge respectively droped to 3.1% and 4.0% from 9.0% and 10.2% and oil degradation rate were 65.6% and 60.8%. At the same time, by gas chromatography - mass spectrometry analysis methods, they analyzed the change of saturated hydrocarbon components and the mass fraction in oil sludge. The long paraffins in oily sludge whose oil mass fraction was 9.0% and 10.2% were reduced by 39.8% and 42.2% respectively. Shulan Jiang[21] studied the effect of the land farming method disposing oily sludge. As a result, the best process conditions include pH value of 7.8, soil temperature of 20 ℃ to 30 ℃, doing the moderate slope repair for land, building drainage system to prevent soil water retention and adding 500 kg chloride fertilizer, 50kg phosphate fertilizer and 50 kg potash fertilizer in 100t hydrocarbon. Guilan Lu, etc[22] improved the traditional soil tillage method, taking turf as biological matrix, and mixing turf with the aging oil sludge according to 1:1 (mass ratio). As a result, turf could significantly enhance bioremediation effect, moreover, the concentrations of salt and alkali significantly reduced (pH from 8.7 to 6.9, salinity from 20.3 g/Kg to 7.3 g/Kg), the concentration of organic matter was increased by 17.3%. The concentrations of effective nitrogen, phosphorus, potassium nutrition element obviously improved. The degradation rate of total petroleum hydrocarbon in aging oil sludge was 38.9%.

2.5 PHYTOREMEDIATION

Phytoremediation is in the oily sludge repair site to plant plant that can contribute to degrade petroleum hydrocarbon such as festuca arundinacea, in order to make oily sludge specific retention rise, make biological toxicity down and make biodiversity complicate. Mang Lu, etc[23] researched the influence of festuca arundinacea on oil hydrocarbon degradation and monitored the hydrocarbon degradation rate of soil and the activity of fluorescein diacetate. As a result, the soil total oil compound degradation rate of rhizosphere and non rhizosphere were respectively 27.4% and 11.8%. The microorganism quantity and the enzyme activity of rhizosphere soil were obviously higher than those of the non rhizosphere soil. Petroleum hydrocarbons would significantly affect hydrolysis effect of fluoresceein diacetate. Compared with no sod system, petroleum hydrocarbon degradation reaction first rate coefficient of planting festuca arundinacea system increased significantly. Bing Zhang[24] researched the method of phytoremediation on disposing oily sludge. As a result, reeds adding highly efficient oil degradation bacteria were all survived, plant root through the adsorption and degradation could further degrade petroleum hydrocarbon. Therefore, by plant rhizospheric adsorption and the joint repair action of plant and microorganism, we could achieve completely free-pollution disposal of oily sludge. Dianxi Wang, etc[25] studied and compared the effect of five plants bioremediation. As a result, the degradation rates of soybean, the first page, festuca arundinacea, corn and sorghum were respectively 34.2%, 28.5%, 26.6%, 23.1%, 20.1%. Meanwhile, they researched the growth-promoting effect of festuca arundinacea rhizosphere bacteria for the seeds of festuca arundinacea. As a result, the microbial strains owning the ACC deaminase activity could enhance the salt resistance of festuca arundinacea.

3 CONCLUSION

With the rapid development of petrochemical industry, how to reasonable dispose oily sludge has become a bottleneck in the development of enterprises. Harmless disposal of oily sludge is the development direction of future research and biological method is a promising technique in harmless treatment technology. Disposal of oily sludge biological methods mainly include two categories. One the one hand, we can put microorganisms efficiently degrading oil in the sludge such as bacillus. On the other hand, by bioaeration and addiing nitrogen and phosphorus nutrients in oil sludge, we can arouse degradation petroleum hydrocarbon activity of indigenous microbial [26] in oily sludge. In the research works, our country is still in the initial stage. The author suggest that from now on, we need to work on the following several aspects. For one thing, we can screen new efficient decomposition petroleum hydrocarbon strains. For another, we can improve the traditional process. Last but not lest, we can optimize operating conditions and shorten the processing cycle.

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