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Research progress on resource utilization and harmless treatment of oily sludge treatment technology

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Abstract: *During the process of oil extraction and treatment, a large amount of oily sludge is generated, which has certain economic value. Improper treatment not only endangers the environment and human health, but also causes waste of resources. Based on the analysis of the physicochemical properties of oil sludge, this article elaborates on the application scope, advantages and disadvantages of methods such as biodegradation, solidification treatment, mechanical centrifugation, solvent extraction, and pyrolysis from two aspects: harmless treatment and resource utilization of oil sludge. It also explores the development path and direction of harmless treatment, resource utilization, and engineering of oil sludge from the perspectives of safety and economy, providing certain reference suggestions for subsequent oily sludge treatment.*

Keywords: *Oily sludge, Harmless treatment, Resources utilization*

1. Introduction

With the enhancement of China's industrial strength, oil has been extensively exploited and used. In 2018, China's consumption of oil reached 620 million tons, and the resulting oily sludge exceeds 5 million tons annually [1]. These oily sludge have a huge output and complex composition, usually containing a large amount of pathogens and heavy metals, which can cause great harm to the surrounding environment. In 2016, China included oily sludge in the National Hazardous Waste List, which belongs to hazardous waste. At the same time, oily sludge contains a large amount of organic hydrocarbon components, which has high potential for resource utilization. Therefore, the correct treatment and secondary utilization of oily sludge is of great significance for achieving resource recycling and protecting the environment. In recent years, there have been some treatment methods for oily sludge, such as biodegradation, oxidation, solvent extraction, hot water washing, pyrolysis [2]. This article summarizes the current treatment technologies for oily sludge and their domestic and international progress, and prospects and explores the future of oily sludge treatment technology.

2. Research background of oily sludge

2.1 Characteristics of oily sludge

Oily sludge is mainly composed of three-phase substances such as oil, water, and slag. In addition, due to the addition of a large amount of chemical agents and water treatment agents in the process of extracting crude oil and subsequent processes in the petroleum industry, oily sludge usually contains solid suspended solids, heavy metals, chemical agents, etc. These substances combine to make the structural properties of oily sludge very stable [2]. Among them, the moisture content of oily sludge is usually relatively high, and the water in oily sludge generally exists in the form of emulsified water [3]. The asphaltene, resin and other substances in oily sludge play a role in interfacial activity, promoting the emulsification of oil and water, and forming a stable state of water in oil and oil in water. The above factors make it very difficult to separate three-phase oil sludge.

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2.2 Current research status of oily sludge

Oily sludge not only pollutes the environment, but from another perspective, it is also an indispensable resource. Based on the technical indicators of reduction, harmlessness, and resource utilization, oily sludge treatment technology has been developed for many years, and many mature technical routes have emerged. This article divides oil sludge treatment technologies into two categories based on their harmless and resource utilization in recent years, as shown in Figure 1. It summarizes and summarizes the advantages and disadvantages of domestic and foreign oil sludge treatment technologies, and looks forward to future oil sludge treatment technologies.

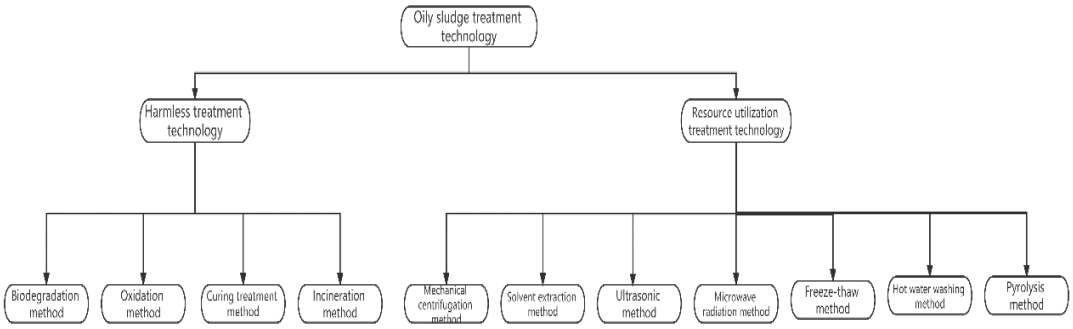

Figure 1: Oily sludge treatment technology.

3. Harmless treatment technology

3.1 Biodegradation method

The biodegradation method mainly utilizes the advantages of strong adaptability and fast metabolic reproduction of microorganisms to decompose hydrocarbons and other substances in oily sludge into pollution-free substances, such as carbon dioxide and water. Biodegradation methods are mainly divided into tillage, composting, and biosurfactant methods [4]. Luo F studied the degradation efficiency of bioreactors on oily sludge, and used FLUENT software to study the optimal process parameters for bioreactors. They found that when the inoculation amount was 15.23% and the temperature was 32.56℃, 6kg of oily sludge was degraded by the bioreactor for 9 days, and the degradation rate of petroleum hydrocarbons reached 86.20%, with an oil content of 1.46%[5].

3.2 Oxidation method

The oxidation method mainly utilizes strong oxidants such as ozone and hydrogen peroxide to decompose large molecule hydrocarbons and hydrocarbon compounds in oily sludge into low toxicity or non-toxic small molecule substances. Currently, the oxidation method mainly includes supercritical water oxidation, O3 oxidation, and Fenton oxidation [6]. Chen Z studied the effect of supercritical water oxidation on shale drilling fluid and found that the use of supercritical water oxidation method resulted in a removal rate of organic carbon in the drilling fluid of 98.44% [7].

3.3 Curing treatment method

The solidification treatment method is to use physical and chemical methods to solidify oily sludge in an inert substrate so that it can be reused. Its essence is to convert hazardous waste into stable substances with poor solubility and weak toxicity to prevent the impact of harmful substances on human health or the environment [8]. Xu L conducted solidification treatment on oily sludge and found that when the mass ratio of cement to oily sludge was 1:2, the solidification effect of the solidified block was the best, and the compressive strength of the solidified block reached the highest. Moreover, adding an appropriate amount of additives can effectively increase the strength of the solidified block [9].

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3.4 Incineration method

The incineration method is to dehydrate oily sludge and place it in a high-temperature environment between 800℃ and 1200℃ to convert it into harmless substances such as carbon dioxide and water for discharge [10]. Lin B and others incinerated the oily sludge from Karamay Oilfield in Xinjiang, and the sample of oily sludge residue after incineration met the national emission standards, proving the feasibility of oily sludge incineration [11].

4. Resource based processing technology

4.1 Mechanical centrifugation method

Mechanical centrifugation method is the use of centrifuges and filters. The principle of use is to use centrifugal force to separate the emulsion in oily sludge, and to separate it based on the density differences of different solid particles and liquid suspensions. In the pre-treatment stage of separating oily sludge, new chemical agents will be added, such as demulsifiers, flocculants, or auxiliary means such as heating [12]. The selection of types depends on the nature of the oil sludge. Wang J studied the effect of additives on the centrifugation effect and found that as the oily sludge is separated, the oil phase undergoes upper and lower layering. As the content of additives increases, the molecular weight of the upper oil phase gradually decreases, indicating that additives have a promoting effect on oil phase recovery [13].

4.2 Solvent extraction method

The solution extraction method utilizes the principle of "similar phase solubility", which means that the solubility difference between the original solvent and the extractant for each component causes them to be unevenly distributed between the two liquid phases. Then, the separation between the components is achieved through the separation of the two liquid phases. In oily sludge, petroleum is easily soluble in organic solvents for the separation of crude oil and other substances in petroleum, and then the solution of the mixed crude oil is separated by distillation to obtain crude oil [14]. Zhao M studied the effect of styrene extractant on oil sludge recovery and found that under optimal conditions, the recovery rate of light oil reached 87.9% [15].

4.3 ultrasonic method

Ultrasonic method is a method that utilizes the phenomenon of cavitation to remove the adsorbed substances of particles inside the oil sludge and break the stable state of oil in water and oil in water [16]. Zhao X used ultrasonic radiation to treat landing oil sludge, and the results showed that ultrasonic radiation improved the recovery rate and dehydration rate of crude oil [17].

4.4 Microwave radiation method

The microwave radiation method utilizes microwave energy to convert into internal energy, even if the microwave energy in the treated oil sludge is converted into thermal energy to heat, decompose, and recover the oily sludge. Due to the higher dielectric constant of water compared to oil, in the case of absorbing microwave energy, water absorbs more microwave energy than oil, which leads to the expansion of emulsified water droplets and facilitates oil-water separation [18], achieving the effect of treating oily sludge. Yao L studied the treatment problems caused by oil sludge scum in refineries. Combining microwave radiation method and ultrasonic method, under the conditions of microwave power of 252W, microwave heating time of 4 minutes, and ultrasonic frequency of 50 W, the oil removal rate of oil sludge reached 53.23%, and the recovery rate of crude oil reached 31.03% [19].

4.5 Freeze-thaw method

The freeze-thaw method mainly involves placing the oil sludge in a low-temperature environment, where the water phase freezes earlier than the oil phase, leading to the expansion of water droplets and the aggregation of the oil phase, which disrupts the stable structure of the emulsion. Later, during the heating and melting process, the oil phase polymerizes through interface action, and then layers with the water phase. During this process, the oil phase and the water phase are separated due to gravity [20].

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Li Y constructed a new suspended continuous freezing/melting tank bottom oil sludge treatment process device based on freeze-thaw technology. The research object was the tank bottom oil sludge with a soil residual oil rate of 22.7%. Under the conditions of freezing temperature -16±0.5℃, freezing time of 8 hours, and melting temperature of 20℃~25℃, the residual oil rate reached 2.6%. After secondary freeze-thaw, the residual oil rate further decreased to 0.5% [21].

4.6 Hot water washing method

The hot water washing method borrows the method of heating the oil sludge, mixing suitable chemical agents in the oil sludge for repeated cleaning, so that the cleaned liquid is divided into a distribution state of slag, water, and oil, and then the oil is gasified and separated [22]. Ren P studied oily sludge from Longdong Oilfield, and achieved a degradation rate of 96.71% by pre cleaning the sludge with chemical solvents and then adding biological bacteria for treatment [23].

4.7 Hot water washing method

Pyrolysis method utilizes the instability of organic matter to undergo cracking or condensation reactions of organic matter in oil sludge under high temperature (500℃~1000℃) oxygen free environment, forming a three-phase substance consisting of gas phase (CO, CO2, etc.), liquid phase (light component crude oil and water, etc.), and solid phase (inorganic minerals and residual carbon) [24-25]. Zheng F studied the effect of pyrolysis end temperature and heating rate on the three-phase products of oil sludge, and found that the pyrolysis end temperature and heating rate promote the generation of low chain hydrocarbons in pyrolysis oil, while medium chain hydrocarbons first increase and then decrease; The final temperature of pyrolysis has a certain impact on the generation of solid products, while the heating rate has no effect on the solid products [26].

5. Conclusions

At present, in order to achieve harmless, reduced, and resource utilization of oily sludge, reduce the oil content of oily sludge to below 3%, and recover a certain amount of energy and products, corresponding treatment technologies are needed. At the same time, due to its complex composition and stable chemical properties, a single treatment technology can often only achieve a few of them. In the future, the treatment technology of oily sludge will inevitably develop towards a phased and multi technology coordinated treatment direction. For example, for large-scale treatment of oily sludge, mechanical centrifugation can be used for dehydration, and then pyrolysis can be used for recycling. This article believes that the current oily sludge treatment technology should be developed in the following aspects:

1) For the biodegradation method, it is possible to select efficient microorganisms for degrading petroleum hydrocarbons, design new bioremediation processes, or use other methods for pre-treatment before using biodegradation to achieve the recovery of petroleum related products.

2) For the mechanical separation method, high-efficiency demulsifiers can be used to improve the separation effect, reduce device energy consumption, or combined with other technologies to demulsify and save energy.

3) For the pyrolysis method, relevant catalysts and biomass should be studied to improve the pyrolysis effect, deeply understand the reaction mechanism of oily sludge in order to better design relevant pyrolysis processes and equipment.

References

[1] Anon. National Bureau of Statistics 2020 China Statistical Yearbook [M]. Beijing: China Statistical Publishing House, 2020.
[2] Di X J, Pan H D, Li D H, et al. Thermochemical Recycling of Oily Sludge by Catalytic Pyrolysis: A Review[J]. Scanning, 2021.
[3] Huang Q, Mao F, Han X, et al. Characterization of emulsified water in petroleum sludge[J]. Fuel, 2014, 118: 214-219.
[4] Zhu Y Q, Tong Le, Liu Q W, et al. Research progress in biological treatment of oily sludge [J]. Liaoning Chemical Industry, 2020, 49 (04): 393-395.

ISSN 2616-5872 Vol.5, Issue 7: 70-74, DOI: 10.25236/AJEE.2023.050710

[5] Luo F. Study on the Flow Field and Operating Parameters of a Biodegraded Oily Sludge Reactor [J]. China Environmental Science, 2022, 42 (4): 1754-1761.
[6] Sivagami K, Anand D, Divyapriya G, et al. Treatment of petroleum oil spill sludge using the combined ultrasound and Fenton oxidation process[J]. Ultrasonics Sonochemistry, 2019, 51: 340-349.
[7] Chen Z, Zheng Z J, Li D Y, et al. Continuous supercritical water oxidation treatment of oil-based drill cuttings using municipal sewage sludge as diluent[J]. Journal of Hazardous Materials, 2020, 384.
[8] Min J. Research on the Catalytic Pyrolysis and Solidification Treatment of Oil Mud Containing Titanium Blast Furnace Slag [D]. China University of Petroleum (East China), 2019.
[9] Xu L. Experimental study on solidification of oily sludge [J]. Environment and Development, 2018, 30 (3): 105-106.
[10] Hou Y F, Huang C Q, Qin Z W, et al. Research progress in oily sludge treatment technology [J]. Contemporary Chemical Industry, 2020, 49 (3): 631-637.
[11] Lin B C, Wu P, Wu L P, et al. Mixed combustion of oilfield oil sludge and coal in a fluidized bed [J]. Journal of Environmental Engineering, 2018, 12 (4): 1237-1245.
[12] Shao L H, Guo T, Shi Y, et al. Research progress in centrifugal treatment technology for oily sludge [J]. Contemporary Chemical Industry, 2014 (2): 263-266.
[13] Wang J, Han X, Huang Q, et al. Characterization and migration of oil and solids in oily sludge during centrifugation[J]. Environmental Technology, 2017, 39(10): 1-9.
[14] Hu G, Li J, Hou H. A combination of solvent extraction and freeze thaw for oil recovery from petroleum refinery wastewater treatment pond sludge [J]. Journal of Hazardous Materials, 2015, 283: 832-840.
[15] Zhao M, Wang X, Liu D, et al. Insight into essential channel effect of pore structures and hydrogen bonds on the solvent extraction of oily sludge [J]. Journal of Hazardous Materials, 2020, 389: 121-126.
[16] Pilli S, Bhunia P, Yan S, et al. Ultrasonic pretreatment of sludge: A review [J]. Ultrasonics Sonochemistry, 2011, 18(1): 1-18.
[17] Zhao X F, Ge D, Zhang X Y. Ultrasonic demulsification combined technology for treating Daqing landing oil sludge [J]. Chemical Progress, 2017, 36 (S1): 489-494.
[18] Binner E R, Robinson J P, Silvester S A, et al. Investigation into the mechanisms by which microwave heating enhances separation of water-in-oil emulsions [J]. Fuel, 2014, 116: 516-521.
[19] Yao L, Chen H X, Zhang D S, et al. Experimental study on microwave ultrasonic pretreatment of oil sludge scum [J]. Energy and Environmental Protection, 2022, 36 (1): 29-35.
[20] Chen Z X. The current status and prospects of oily sludge treatment technology [J]. Oil and Gas Field Surface Engineering, 2020, 39 (10): 1-7.
[21] Li Y C. Research on the process technology for recovering crude oil from tank bottom sludge [D]. Dalian: Dalian University of Technology, 2008.
[22] Wang X G, Zhai K G, Yang Z. Progress in oily sludge treatment technology [J]. Refining Technology and Engineering, 2020, 50 (08): 61-64.
[23] Ren P, Zhao M. Research on Chemical/Biological Combined Treatment of Oily Sludge Technology [J]. Environmental Protection of Oil and Gas Fields, 2019, 29 (5): 50-53.
[24] Tian Y, Li J B, Yan X Y, et al. Co-pyrolysis of metal contaminated oily waste for oil recovery and heavy metal immobilization [J]. Journal of Hazardous Materials, 2019, 373: 1-10.
[25] Lin B, Huang Q, Mujahid A, et al. Continuous catalytic pyrolysis of oily sludge using U-shape reactor for producing saturates-enriched light oil[J]. P. Combust. Inst. 2019; 37: 3101-3108.
[26] Zheng F, Li H W, Lin F W, et al. The pyrolysis characteristics and pollutant release characteristics of Daqing tank bottom oil sludge [J]. Progress in Chemical Industry, 2022, 41 (01): 476-484.