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Research Progress on Treatment Technology of Produced Water by Adsorption Method

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Abstract. Produced water is the largest by-product of oil production. Studying its high-efficiency treatment technology is one of the key issues in the sustainable development of oilfields. The adsorption has the characteristics of low cost, high efficiency and no secondary pollution, and has significant effects in the treatment of produced water. This paper introduces the adsorption technology. The research progress of the domestic and international adsorption treatment of oilfield produced water was summarized. The effects of different adsorbents on oilfield produced water treatment are briefly described, which points out a new research direction for the development of future adsorbent technology.

1. Introduction

As the amount of oil extraction continues to increase, the output of produced water in the oilfield is also increasing. The oil and gas industry will also have an adverse impact on the environment while producing oil. During the process of oilfield exploitation oilfield, the produced water is the water which is separated from produced liquid by the process of dewatering. It is the largest by-product of oil production in the oil field. The produced water in the oilfield contains a large amount of organic matter, inorganic salt ions, oils, corrosives and radioactive products. Its efflux will cause continuous pollution to the ecological environment, and its composition is extremely complicated [1]. Different types of oilfield produced water need to be treated with different treatment processes to achieve the re-injection criteria. Therefore, the treatment of oilfield produced water has brought challenges to the sustainable and stable production of oilfields, and its management has become an important issue for environmental supervision departments. China needs to deal with a large amount of oilfield produced water every year [2], and its output is increasing year by year. Most of the produced water in the oilfield is used to reinject the formation, and a small amount of produced water is directly discharged into the environment. The produced water used for reinjection of the stratum needs to reach the water quality index of the re-injection water in the oilfield, and the produced water that was directly discharged should also meet the criterion of wastewater discharge given by the environmental protection department. Therefore, the efficient treatment of oily wastewater has become a key issue that needs to be solved in the continuous exploitation of oil fields, and the discharge of produced water also poses a serious challenge to environmental protection.

At present, the main oilfield produced water treatment using some conventional processing technology, such as physical methods: gravity separation, centrifugal separation process, coalescence method, filtration method and membrane separation. Chemical methods: chemical demulsification method and chemical oxidation method. Physical and chemical method, salting-out method, coagulation and sedimentation method, and electrochemical method. Biological method: activated sludge method, biological membrane method, oxidation pond and anaerobic contact method. The



method of combination between them. There are also many related review reports the research progress of the processing technology [3-4]. In recent years, membrane technology has become a research hotspot due to its characteristics of high efficiency and non-pollution. Among them, Xu Xiaodong, Lin Aiguo, et al. has summarized the application of membrane technology in oilfield produced water [5-6]. However, there are few reports about the research on adsorbent treatment of oilfield produced water. Therefore, this is summarized below.

2. Characteristics and Applications of Adsorbents

The adsorption method has become a hot spot in the research of produced water treatment technology because of its advantages of low cost, good removal effect and no secondary pollution. The main principle is to absorb the pollutants in the wastewater by utilizing the lipophilicity and chemisorption of the adsorbent. In addition, the treatment of some macromolecular organic pollutants that are difficult to remove by other methods is particularly significant. Therefore, the adsorption method has an irreplaceable role in the field of water treatment. Adsorbent treatment of heavy metal wastewater [7-9], printing and dyeing wastewater [10-13], chemical wastewater [14] and other wastewaters have been reported in many literatures, many of which have been successfully applied in industry. However, its application in oilfield wastewater treatment is still in the experimental stage. At present, the adsorbents used in oilfield produced water treatment are mainly divided into: clay adsorbents, carbonaceous adsorbents, adsorbents prepared by waste and other adsorbents.

2.1. Clay Adsorbent

2.1.1. Bentonite. The main component of bentonite is montmorillonite, which is prone to interlayer peeling and expansion under the action of solvent. As a result, bentonite has a large surface area and thus has a strong adsorption capacity, which can effectively remove organic pollutants in wastewater. Moazed et al. [15] reported that organic bentonite treatment produced water from the Esteban well in Canada. The initial oil content of the produced water was 231 mg/L and the pH was 6.8. The experimental results showed that the oil removal rate of the produced water from the oil well treated with organic bentonite could reach 88-89%. Subsequently, Moazed et al. [16] also used the combined adsorbent of organic bentonite and anthracite to treat the same produced water, in which the mass ratio of organic bentonite and anthracite was 3:7, the average particle size of the combined adsorbent was 2.1mm, and the porosity was 45%. It was found that after 5g of composite adsorbent was added and adsorbed for 15 minutes, the oil content in the produced water decreased dramatically from 231mg/L to less than 50mg/L. However, with the increase of adsorption time, the oil content in the produced water basically remains unchanged, indicating that the adsorbent had reached saturation state. It was also found that the oil removal rate increased with the increase of the amount of compound adsorbent.

2.1.2. Vermiculite. Vermiculite is a natural mineral, belonging to silicate, which is widely used in wastewater treatment because of its good ion-exchange and adsorption. Silva et al. [17] investigated the effect of vermiculite on the adsorption of crude oil in wastewater. The results showed that the adsorption of hydrated vermiculite on crude oil was poor, while expansion vermiculite and hydrophobic vermiculite had a good adsorption effect on crude oil. The experiment also found that for every 10% increase of the hydrophobic group of the hydrophobic vermiculite, the hydrophobic meteorite can increase the adsorption capacity by 50% compared with the expanded vermiculite. Mysore, etc on the basis of Silva, etc. [18] used expansion vermiculite and hydrophobic vermiculite as adsorbents to treat refinery wastewater. The results showed that the oil removal rate of refinery wastewater treated with expanded vermiculite as adsorbent was higher than that of hydrophobic vermiculite, but the oil removal rate of both was relatively low, with the oil removal rate of expanded vermiculite being 57%, while the oil removal rate of hydrophobic vermiculite was only 43%. Therefore, it can be found that vermiculite is less effective in treating oily wastewater from oil field.

2.2. Carbon Adsorbent

2.2.1. Powdered activated carbon. Powdered activated carbon is mainly made of wood chips and husks as raw materials. After steam activation, it is refined and pulverized into micro-powder materials. It has the characteristics of large specific surface area and strong adsorption capacity, and is widely used in wastewater treatment. Khaled et al. [19] examined the oil removal effect of powdered activated carbon on oily wastewater. The experimental results showed that the mass of powdered activated carbon increased from 0.1g to 0.5g under the condition of initial oil content of 600mg/L and stirring time of 30min. The oil removal rate can be increased from 20% to 61%. When the initial oil content of the wastewater is 836mg/L, 0.5g of powdered activated carbon is added and stirred for 2h, the oil removal rate can reach 82.78%. And under the same conditions, 1g of powdered activated carbon is added and stirred for 4h and the oil removal rate was as high as 93.54%. In this experiment, they also found that the oil removal rate increases with the increase of dosage and contact time of powdered activated carbon, and decreases with the increase of initial oil content of wastewater.

2.2.2. Carbon deposition. Carbon deposition is the main component of particulate matter from diesel exhaust, which is of concern to researchers due to its low price and high oil removal efficiency. The literature [19] found that the oil removal effect of carbon deposition under the same conditions is better than that of powdered activated carbon. Because the porosity and surface area of carbon deposition are larger than that of powdered activated carbon and the oil removal rate of carbon deposition is more than 10% higher than that of powdered activated carbon. The experimental results show that the contact time, the initial oil content of the wastewater and the dosage of adsorbent all have an effect on the oil removal rate of carbon deposition, which is consistent with that of powdered activated carbon.

2.3. Adsorbent Prepared from Waste

2.3.1 Eggshell. Muhammad et al. [20] used eggshells as biosorbents to remove dissolved oil and dispersed oil from oily wastewater. The surface morphology of the eggshell was characterized by scanning electron microscopy (SEM). It was found that the eggshell is a semi-permeable biofilm with complex porous structure, so it has strong adsorption in the natural state. The experimental results show that the eggshell can effectively remove the oily substances in the oily wastewater, and it is found that the oil removal rate will increase with the increase of the eggshell addition. When the initial oil content in oily wastewater is 194mg/L and the addition amount of eggshell is 200mg/L, the oil removal rate can reach 77.83%. And when the adding amount of egg shell is 1800mg/L, the oil removal rate can reach 100%. The result shows that the eggshell as adsorbent has a good application prospect. It not only has good adsorption characteristics, but also can turn waste into treasures, which is in line with the characteristics of the new adsorbent "cheap, high efficiency, no secondary pollution".

2.3.2 Banana peel. EI-Nafaty et al. [21] reported the use of banana peel to remove oily materials from oil produced water. The surface morphology of banana peel was characterized by SEM. It was found that there is a strong adsorption in the place where the layered material is deposited. And the charged oil droplets in the water will destroy the double and triple bonds in the banana peel structure to initiate the reaction and exchange their ions to neutralize the charge. It can eliminate the chargeability of the oil droplets, thereby reducing the repulsion between the oil droplets, which is conducive to the accumulation of oil droplets. The experimental results show that Banana peel has excellent oil removal effect. When the additive amount of banana peel is 10mg/L, the oil removal rate can reach 94.51%. And when the addition amount of banana peel is 50mg/L, the oil removal rate is 100%. At the same time, the effects of pH, adsorption time and temperature on oil removal were also analyzed in the literature.

2.4. Other Adsorbents

High oil-absorbing resin is a new kind of organic adsorbent, which is a functional polymer oil-absorbing material prepared by several oleophilic monomers through a certain degree of cross-linking polymerization. It has good heat resistance, cold resistance, and density less than water does not absorb water, oil absorption speed, not aging. In foreign countries, new high oil - absorbent resins have been widely studied and applied [22]. Li Feng, et al. [23] prepared copolymer high oil absorption resin by suspension polymerization with methacrylate as monomer. Under the condition of polymerization temperature 700 °C, the mass ratio of the high oil absorption resin to the monomer is 65:20:15, and the dispersing agent is 0.5%, it was found that the high oil absorption resin oil absorption performance is the best, oil absorption ratio of 7.86g/g. After the experiment, the high oil absorbent resin and polypropylene were combined in a certain proportion to produce the high oil absorbent resin/polypropylene composite oil absorbent material. The experimental results show that the overall oil absorption performance is good. When the mass ratio of the high oil absorption resin is 5%, the adsorption material has the best overall performance, with oil absorption ratio of 11.5g/g, water absorption rate of 6.6% and oil retention rate of 96.3%. It is found that the high oil absorbing resin/polypropylene composite oil absorbing material has great application prospect in the recovery and treatment of oil floating on water surface.

Xin Shanshan, et al. [24] modified chitosan-acrylate composite resin was synthesized by suspension polymerization method. Chitosan was modified by A151, with factors analysis and orthogonal experiment. The result shows that, reaction power was 100W, time of reaction was 1h, the ratio of monomers was 1:1.5, BPO was 2.0% (wt), crosslinker was 1.5%(wt), PVA was 10%(wt), modified chitosan was 1.0%(wt). Adsorption capacity was found to be maximum at optimal condition. The as-prepared resin presented porous microspheres structures and the volume expansion rate reached 50 times.

3. Conclusion

The above research shows that the adsorbent method has the advantages of high oil removal rate, no secondary pollution and low treatment cost, compared with the oily wastewater treatment process commonly used in oil fields. However, due to its poor treatment effect on suspended solids, it is still only in the experimental research stage. The adsorbent has a good removal effect on the organic pollutants in the oily wastewater, so it can be considered to be applied to the pretreatment process of the oily wastewater.

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