

An Overview on Oily Wastewater Treatment Technology for Ships

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Abstract

Since the 21st century, with the increasing growth of the global economy, the world's countries are becoming more and more closely linked, relying on the sea and the ship transport has become the main mode of transport of foreign trade, but the shipping industry is booming at the same time also caused a lot of irreversible damage to the marine ecological environment, the ship's oily wastewater from a wide range of sources, the production of huge, complex water quality and environment has always been the difficult problem of sewage treatment, the ship's oily wastewater treatment processes and theoretical methods. This paper summarises and analyses the process and theoretical methods of oily sewage treatment for ships by reviewing the relevant literature at home and abroad, and points out its future development trend. The results of the research can provide theoretical and technical support for the development and application of oily wastewater treatment process for ships.

Keywords

Ships; Oily Wastewater; Treatment Technology.

1. Introduction

In the 21st century, with the increasing growth of the global economy, the links between the countries of the world are getting closer and closer, relying on the sea ship transport has become the main mode of transport for foreign trade, but the booming development of the shipping industry has also caused a lot of irreversible damage to the marine ecosystem, oil substances into the ocean will form an oil film covering the surface of seawater, preventing sunlight from penetrating through, which will have a direct impact on the photosynthesis of plants in the ocean. This will directly affect the photosynthesis of plants in the ocean, preventing phytoplankton and benthic plants from obtaining enough light energy, which will lead to the death of large areas of marine plants in a region. In recent years, as people around the world have become more aware of environmental protection, the pollution of the marine environment by oily waste water from ships has received widespread attention on a global scale. International Maritime Organization in 1973 issued the "International Convention for the Prevention of Pollution from Ships 1973" to solve the problem of oily wastewater discharged from ships, how to improve the treatment effect of oily wastewater treatment equipment for ships, has become the top priority of the current industry research [1].

2. Oily Sewage from Ships

2.1. Sources of Oily Sewage from Ships

Oily wastewater has been a difficult problem in wastewater treatment due to its wide range of sources, huge production and complex water quality environment [2]. According to the different locations of oily wastewater generation from ships, oily wastewater from ships can be classified into three major categories, which are oily bilge water, dirty ballast water and engine room bilge water [3].

2.1.1. Oily Bilge Water

Oily bilge water refers to the wastewater produced by ships when carrying out operations such as cabin cleaning and maintenance, which contains a large amount of oily substances, and the oil content of oily bilge water can reach 2000 to 10000 ppm, which, if not treated in time and directly discharged into the sea, will lead to serious damage to the ecological environment. There are two main reasons for the formation of oily bilge water: firstly, when the ship transports different goods, there may be residual oily substances in the cargo hold, and in the process of cleaning and maintenance of the ship's hold, these oily substances and water are mixed to form oily bilge water; secondly, during the operation of the ship, the staff need to carry out maintenance on the inner wall of the bunker, and in the process of maintenance, due to the washing of the inner wall of the bunker and the pipeline, a large amount of oily wastewater is brought out. In the process of maintenance, the cleaning of the oil tank walls and pipelines will bring out a large amount of oily wastewater.

2.1.2. Sewage Ballast Water

Ship's ballast water refers to the water injected or discharged into the ship's tanks in order to maintain the stability of the ship under different load conditions. The role of ballast water is mainly reflected in two aspects: on the one hand, when the ship sails unloaded, it can ensure that the ship has a certain draught depth; on the other hand, when the ship is loaded, the ship is in a stable sailing posture by adjusting the amount of ballast water in the ballast tanks [4]. When seawater is injected into the cargo or ballast tanks, this water combines with the viscous oil on the bulkheads to form a kind of oily ballast water [5]. When a ship encounters extreme weather, sometimes ballast water is also injected into the ship's oil tanks to maintain the ship's normal travelling, when the oil content of the ship's ballast water can be up to the range of 4000~7000 ppm, the oil content of the ship's ballast water is unstable, and if it is not treated and directly discharged into the sea, it will pollute and damage the marine ecological environment.

2.1.3. Bilge Water

Bilge water refers to the oily sewage formed by the leakage of various wastewater and waste oil into the bilge of the ship. Ship equipment maintenance, repair and cleaning activities will produce a variety of wastewater, and mechanical equipment, oil-resistant hoses and pipelines aging, joints, valves, loose easily lead to a variety of oil "running, bubbling, dripping, leaking", these wastewater, waste oil in the ship's compartments, decks, equipment, oil pumps and pipelines and other areas, easy to seepage, and then mixed in the bilge to form oil pollution [6]. And then mixed in the bilge to form oil pollution. These oil and water pooled in the bilge, after the ship's constant shaking, thorough oil-water mixture, bilge water oil content can be up to 2000 ~ 5000 ppm [7].

2.2. Hazards of Oily Sewage from Ships.

If the oily sewage discharged into the sea by ships exceeds the purification capacity of seawater itself, it will cause marine pollution, which will have a serious impact on marine resources, human beings and the ecological balance [8]. From the perspective of ecology, society and human beings, this harm is particularly complex and profound:

2.2.1. Ecological Hazards

Oily substances contained in oily sewage from ships entering the sea will form an oil film that covers the surface of seawater and prevents sunlight from penetrating through it, which directly affects the photosynthesis of plants in the sea and prevents phytoplankton and benthic plants from obtaining sufficient light energy, which will result in the death of large areas of marine plants in an area. The direct discharge of oily wastewater from ships into the sea does not only cause damage to marine plants, but also some fish and shellfish and other animals may

suffer from poisoning, developmental deformities and reproductive disorders after ingesting the oil, which will lead to a decline in the diversity of marine organisms and have a chain reaction on the entire food chain, and the decomposition of oil will also consume a large amount of dissolved oxygen, resulting in the death of a large number of marine organisms [9]. For example, in March 1989, the U.S. oil tanker Exxon Valdez ran aground, resulting in about 30000 tonnes of crude oil into the ocean, causing serious marine pollution, inducing the deaths of nearly 4000 sea otters and 300000 seabirds, and it is predicted that the recovery of the marine ecosystem in the region will take more than twenty years, resulting in economic losses of about eight billion U.S. dollars. economic losses of about eight billion US dollars [10].

2.2.2. Dangers to Society

The occurrence of marine oil spills will not only cause serious harm to the ecological environment around the sea, but also cause huge direct or indirect economic losses to the society, including the coastal tourism industry, the marine fishing industry, the aquaculture industry, and the marine scientific research [11]. Fish and other aquatic products may be contaminated in polluted waters, which will lead to a decrease in the yield and quality of aquatic products, causing losses to the fisheries and aquaculture industries. Beautiful beaches and coastlines are important tourism resources, and oily effluent discharges from ships cause oil pollution to remain on beaches, which affects the landscape and ecological environment of beaches, which in turn negatively affects the tourism industry in coastal areas, and tourists may avoid travelling to polluted areas, leading to a decline in the local tourism industry.

2.2.3. Hazards to Human Survival

The ocean is an important part of the ecosystem and plays a significant role in human society [12]. Toxic substances in oily effluent from ships may be transferred through the food chain to seafood ingested by humans, and human consumption of contaminated fish and shellfish and other aquatic products may lead to poisoning and health problems, making public health a potential threat. Volatiles contained in oily waste water may adversely affect the air quality in the sea area and may also negatively affect the respiratory system of the surrounding residents and staff.

3. Treatment of Oily Wastewater from Ships

In order to protect the marine ecosystem and maintain ecological balance, the effective treatment of oily sewage from ships has become particularly important, at present, the traditional treatment process has been very difficult to meet the requirements of the new regulations. For the nature, characteristics and discharge standards of oily water, the treatment of oily water in the bilge of the ship is limited by the environment of the machine, the comprehensive characteristics of the ship itself, the treatment system should have a small size, high efficiency, easy to operate and bumps and other characteristics. Ship's oily sewage treatment methods can be divided into three categories: physical method, chemical method and biological method.

3.1. Physical Method

Physical method is a basic method to treat oily wastewater from ships, mainly through filtration or adsorption and other physical means to separate out the oil substances, at present there are a lot of physical method to treat oily wastewater from ships, such as gravity separation technology, membrane separation technology and adsorption separation technology, etc., and its principle and characteristics are shown in Table 1.

Table 1. Principles and Characteristics of Different Physical Methods for Treating Oily Sewage from Ships

Technical name	Processed object	Theory	Characteristic
Gravitational separation ^[13]	Oil slick	Difference in density between oil and water	Oil-water separators use the principle of gravity separation, by adjusting the speed of water flow and the residence time of the oil-water mixture, so that the oil substances are separated and precipitated at the bottom of the sedimentation tank, the shortcomings are that the ship is easy to affect the effect of the separation of the ship's swaying
Membrane separation ^[14]	Emulsified oil	Selective permeability of microporous or nanomembranes	Membrane separation technology can achieve effective separation of small particles and dissolved oils, but the membrane is susceptible to contamination, which reduces the effectiveness of the treatment.
Adsorption ^[15]	Emulsified and dissolved oils	Adsorption of oil molecules in oily wastewater using activated carbon or zeolite, etc.	Adsorption method can efficiently remove oil substances in oily wastewater, and easy to operate, but the adsorbent will be saturated after adsorbing a certain amount of oil, and need to be replaced frequently.

3.2. Chemical Method

Chemical methods are used to remove oil from oily wastewater by breaking down, oxidising or precipitating the oil through chemical reactions. The oil in the oily water mixture is emulsified to form tiny particles by the addition of appropriate chemicals such as aggregating agents, these can be aggregated to form a precipitate and steps such as filtration separate them. There are many current processes for treating oily sewage from ships using chemical methods, as shown in Table 2.

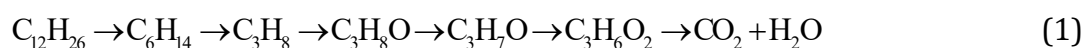
Table 2. Principles and Characteristics of Different Chemical Methods for Treating Oily Sewage from Ships

Technical name	Processed object	Theory	Characteristic
Coagulation ^[16]	Emulsified oil	By adding coagulant to the oily sewage to make the oil in the sewage emulsified into fine particles, aggregated with each other to form large alum flowers, through natural gravity sinking method to remove them.	Advantage is easy to operate, applicable to multiple scenarios, the disadvantage is that the coagulant cost is high, easy to cause secondary pollution
electrochemical method ^[17]	Emulsified oil	Electrochemical method is to use the electrolytic oxidation and electrolytic reduction of the applied power supply to complete the degradation of sewage contained in ships, which is a very efficient treatment method.	The method can not only be used alone, but also can be coupled with other water treatment methods, which in turn makes the degradation efficiency higher. However, the disadvantages of the electrochemical method are high equipment requirements and high cost investment.
advanced oxidation ^[18]	Emulsified oil	Degradation of organic matter using strong oxidising active substances such as hydroxyl radicals (-OH)	Excellent degradation effect on difficult organic matter.

3.3. Biological Method

The biological method is a method of treating oily sewage by utilising the biodegradation of micro-organisms. Through the introduction of specific microorganisms capable of decomposing oil substances, the oil substances in oily sewage from ships are converted into harmless substances, such as water and carbon dioxide. The biological method has the advantage of efficient degradation of many kinds of oil substances, and the treatment effect of oily wastewater is better. Meng Zhuo Ni ^[19] from Guizhou University screened *Serratia marcescens* and *Fusarium axysporum* with 12h oil degradation rate as high as 88.21%; Gorgia et al. ^[20] used phenanthrene and phenol as a carbon source to isolate the *Citrobacter* strains from the actual wastewater, and the isolated strains were used to treat the high and low concentration bilge water, and the results showed that the COD removal reached 83% and 53%, respectively; Aikaterini et al ^[21] used isolated pure aerobic strains and mixed aerobic anaerobic cultures for the treatment of actual bilge wastewater test, and the isolation of three strains with good biodegradation capacity was obtained, and the aerobic mixed strains showed a COD removal rate of 59%, while the mixed strains showed a COD removal rate was 34%; Qunluo et al ^[22] isolated 11 strains of bacteria with oil degradation function from ship bilge oil sewage water and used these strains to degrade the mixed wastewater of bilge oil sewage and marine diesel oil, and the experiments found that: compared with the bilge oil wastewater, the bacterial strains have higher degradation rate of mixed oil, and the degradation rate of 9 of these strains was higher than 50%.

However, the application of biological methods is subject to some limitations, such as more demanding environmental conditions such as temperature and pH, and more complex treatment processes that require precise control. Therefore, in practical ship transport, biological methods are usually used in synergy with other methods to better adapt to different environments and effluent characteristics ^[23]. In the biological treatment process, the efficiency of microbial degradation of pollutants in water can be improved by enriching microorganisms, providing nutrients, increasing contact area, maintaining microbial activity, and regular renewal to maintain the stability and efficiency of the biological treatment system. The reaction process of petroleum hydrocarbon degradation is shown in Equation 1, which is a complex biological process in terms of the reaction process, mainly involving the metabolic activities of microorganisms. The process can be summarised as an initial hydrolysis reaction in which large molecules of petroleum hydrocarbons (e.g. crude oil, heavy oil, etc.) are first decomposed into smaller molecules of hydrocarbons, such as alkanes, olefins and aromatic hydrocarbons by hydrolytic enzymes produced by microorganisms, and then small molecules of hydrocarbons are converted into alcohols through primary oxidation, and then alcohols are further oxidised to acids and ketones, which are further oxidised into carboxylic acids, and the carboxylic acids are ultimately oxidised completely to carbon dioxide and water.



Biological treatment technology for oily wastewater from ships includes two main forms: anaerobic biological treatment and aerobic biological treatment. Anaerobic biological treatment includes anaerobic expansion bed treatment, anaerobic pool treatment, anaerobic sludge bed treatment, etc. Aerobic biological treatment is to make use of aerobic microorganisms to degrade and metabolise pollutants in the water in an oxygen-rich environment. Aerobic biological treatment includes contact oxidation treatment, biofilm treatment, activated sludge treatment and biological enzyme treatment. Biological treatment technology is widely used in wastewater treatment due to its advantages of high cost-effectiveness, the ability to effectively treat a variety of organic pollutants, and does not produce

secondary pollution. At the same time, this technology is also in line with our country to promote the construction of ecological civilisation, to achieve green development, recycling and low-carbon requirements and is highly favoured.

4. Conclusion

Existing marine oily wastewater treatment technology can be divided into physical, chemical and biological methods based on the principle of physical method is commonly used to remove dispersed oil, physical method of adsorption can remove dissolved oil, filtration method can remove emulsified oil; chemical oxidation method can deal with dissolved oil, electrochemical method of removing the emulsified oil has a better effect; biological method can deal with lower concentrations of oily wastewater from the ship oil in the oil of a smaller particle size. However, the composition of oily wastewater from ships is complex, and a single process is difficult to make the effluent water quality meet the standard, in the future, a variety of treatment processes can be used in combination with each other, which can make the best use of their strengths and avoid their weaknesses, and take into account the treatment effect and cost, and on the basis of scientific optimisation, improvement and combination, and ultimately develop highly efficient oily wastewater treatment technology and equipment for ships to adapt to ship's characteristics and the environment.

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