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Treatment Strategies for Reducing Oil Contaminants in Wastewater

Juan Feron Ndruru[1*], Ignatia Marlin Pongoh[2], Niken Adelia Agustin[3], Temmy Wikaningrum[4]

[1,2,3,4]Environmental Engineering Department, Faculty of Engineering, President University, Bekasi
***Correspondent email**: juan.ndruru@student.president.ac.id

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Abstract
The more humans need to develop, the more waste will be generated from by-products of an industry's operational processes. One of the most waste in produce, namely wastewater contaminated by oil. Oil waste not only pollutes aquatic ecosystems but the impact of waste oil itself can be very dangerous for human health. Therefore, it is necessary to process wastewater contaminated with this oil. On the one hand, the development of innovation also makes the methods of processing contaminated waste more varied. Therefore, there is a need for a study to determine which wastewater treatment processes are effective, especially for wastewater that contains oil. The research methodology of this journal itself uses a qualitative method with a literature review approach. So that the results obtained from the comparison of the efficiency of several processing methods such as membrane technology, electrocoagulation, adsorption, and combination. The technology at an affordable cost for simple cases can utilize microbial bioremediation techniques, but this will take a long time. Meanwhile, to obtain good results and affordable costs, the adsorption method is the right choice. But even so, it still needs to be reworked related to the efficiency beside the cost of each processing method.
Keywords: *oily wastewater, wastewater treatment, oil removal, membrane technology, electrocoagulation, adsorption, combination treatment*

Abstrak
Semakin berkembangnya kebutuhan manusia, maka semakin banyak pula limbah yang dihasilkan dari produk sampingan proses operasional suatu industri. Salah satu limbah yang paling banyak dihasilkan yaitu air limbah yang terkontaminasi minyak. Limbah minyak tidak hanya mencemari ekosistem perairan melainkan dampak dari limbah minyak sendiri bisa sangat membahayakan kesehatan manusia. Oleh karena itu perlu dilakukannya proses pengolahan air limbah yang terkontaminasi dengan minyak ini. Di satu sisi, semakin berkembangnya inovasi juga menjadikan semakin bervariasinya cara pengolahan limbah yang terkontaminasi. Oleh karena itu perlu adanya kajian untuk menentukan manakah proses pengolahan air limbah yang efektif terkhusus untuk air limbah yang memiliki kandungan minyak. Metode penelitian artikel ini menggunakan metode kualitatif dengan pendekatan literatur review, sehingga didapatkan hasil dari perbandingan efisiensi beberapa metode pengolahan seperti teknologi membran, elektrokoagulasi, adsorbsi dan kombinasi. Adapun teknologi dengan biaya yang terjangkau untuk kasus yang sederhana dapat memanfaatkan teknik bioremediasi mikroba, namun teknik ini butuh waktu yang cukup lama. Sementara untuk memperoleh hasil yang baik dan biaya yang terjangkau, metode adsorpsi adalah pilihan yang tepat. Namun demikian, masih perlu pengkajian ulang terkait dengan efisiensi selain biaya dari masing-masing metode pengolahan.
Kata Kunci: *air limbah berminyak, pengolahan air limbah, pengentasan minyak, teknologi membran, elektrokoagulasi, adsorpsi, pengolahan kombinasi*

1. Introduction

In this current era where technological advances are increasingly advanced, there are so many industries are built in order to fulfill the needs of people. The existence of some industries of course generates waste that should be managed or treated. Fossil fuels, such as petroleum and natural gas, are the most important hydrocarbon products in the modern world as an irreplaceable resource combined with rising energy demands [1]. As fossil fuels are still being used by most industries, it generates oily wastewater that needs to be treated to be safe water that is ready to discharge or reuse [2]. Other industrial processes that produce oily wastewater can include metal smelting, food processing, dyeing, municipal sources, and others. Oily wastewater can harm ecological resources and functions, jeopardize aquatic systems, and harm human health if it is dumped into the environment. In view of scarce water resources,

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serious environmental pollution, and increasingly strict disposal standards, the treatment and recycling of oily wastewater is a pressing issue in environmental technology [3].

Treating oily wastewater is necessary because it is relatively harmful not only for the environment but also for human health, it is due to the toxic compound that exists in oily wastewater. For plants and animals, oily wastewater can inhibit their growth. And for humans, it contains the carcinogenic compound that triggers the growth of cancer cells [4][5].

There are various ways to treat oily wastewater to remove the oil from wastewater. They will surely have the respective considerations, such as costs, achieved standard levels, the concentration of oil or other hazardous waste that needs to remove, and many more aspects. All industries that generate oily wastewater should treat their wastewater before discharging it to the river or reutilizing it. Therefore, knowing and understanding the treatment strategies of oil removal from wastewater is really important in order to find the right and proper ways to treat oily wastewater especially in reducing oil contaminants from wastewater [2].

2. Material and Methods

This journal approached a literature review, which also included media like Google Scholar, Google, and Connected Journal. There were sixteen references that were used as the literature review in accomplishing the paper starting from 2016 to 2021. A literature review is a piece of academic writing that demonstrates an in-depth knowledge of academic literature on a certain topic. A literature review has four basic goals; to summarize the literature, to survey the literature, to critically analyze the information gathered by identifying gaps in current knowledge, to show limitations of theories and perspectives, to formulate areas for further research, and to review areas of controversy, and to present the literature in an organized manner [6][7].

3. Results and Discussion

The study focused on finding the most efficient way to treat oil contamination in wastewater through a comparison between some of the case studies to remove oily wastewater from several industries. As one of the most important natural resources in this modern era, oil or petroleum is mostly used as energy sources for various industries, whether used for manufacturing industry or event consumer needs. Unfortunately, extraction of extensive oil, transportation, and use, often leads to accidental oil spills which eventually pollute the surrounding environment, especially the aquatic environment. As oil spill causes hazard whether for the plant, animal, or event for human, it is important to the industry, or event government to take action for treating and improve the oil spill clean up strategies.

Commonly, some industries also produce wastewater that contains oil as a byproduct. So, based on literature, here are some industries as sources of oily wastewater:

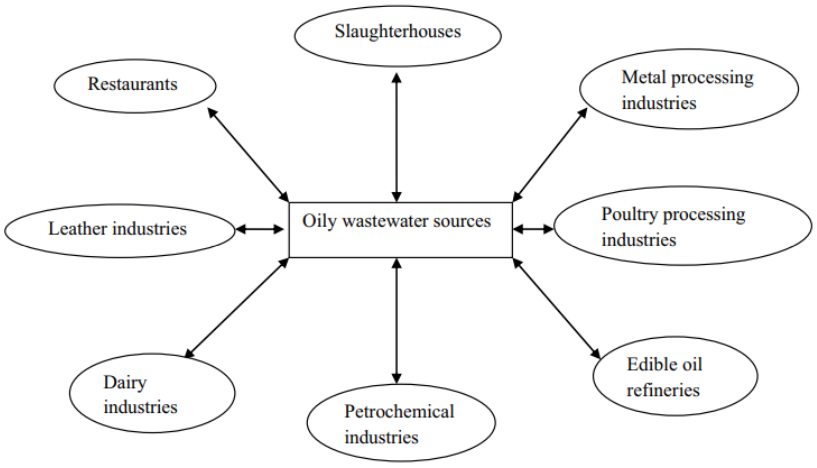

Fig. 1. The industry as sources of oily wastewater
Source: ref. [4]

Based on the diagram above, the industry that expels oily wastewater are slaughterhouse, metal processing industry, poultry processing industry, edible oil refineries, petrochemical industries, dairy

industries, leather industries, and restaurants. Actually for wastewater treatment that is contaminated by oil has a very strict policy for discharging, reusing, or even treating wastewater [8]. There are two categories of oily wastewater treatments, the first is traditional approaches that include chemical coagulation, flotation, sedimentation, and gravity separation [4], and the second is advanced approaches. Here are some kinds of methods with the efficiency of each method.

3.1 Membrane Technology

Membrane technology is one of the methods to treat oily wastewater, there are some kinds of membrane technology methods such as polymeric membranes, ceramic membranes, and nanomaterial-based membranes. When we talk about membrane, by definition membrane is tinny layers that layering material whether inorganic or organic to separate particles from the fluid. In the separation processes in oily wastewater treatment, also include the application of porous material to separate the pollutant [9].

Table 1. Membrane technology efficiency

Oily wastewater type	Treatment effect
Biodiesel water effluent	75% COD; 55% BOD; 92% TS; 96% TDS and 30% TSS
Oil-water emulsion from a crude oil refinery, India	93% oil
Synthetic oil-water emulsions	98.8% O&G
Synthetic oil-water emulsion	> 98% oil; < 59 mg/L COD
Raw oily wastewater from Tehran refinery, Iran	85% O&G; 100% TSS; 98.6% turbidity and > 95% TOC
Raw oily wastewater from Tehran refinery	31.6% TDS; 96.4% turbidity; 94.1% TSS and 97.2% O&G
Wastewater from oil refinery, Tehran	78.1% COD and 90.4% TOC

Source: [4]

By membrane technology, it requires no chemicals, require less energy. Based on size, membrane filtration can be categorized into reverse osmosis, nanofiltration, microfiltration, and ultrafiltration.

3.2 Technology of Electrocoagulation Treatment

Electrocoagulation is a technology that uses the principle of releasing coagulant inside by electrolytic dissolution of metal ions from metal electrodes after an electric current is applied, thereby simultaneously producing hydroxyl ions and hydrogen gas [10]. Basically, there are some advantages and disadvantages of electrocoagulation, the advantages are environmental friendliness and highly effective processes. Meanwhile, the disadvantages are high energy used and costly [11][12].

Table 2. Efficiency of electrocoagulation treatment technology

Oily wastewater type	Operation condition	Treatment effect
Biodiesel wastewater	Current density 8.32 mA/cm^2, pH 6.0, 25 min	97.8% O&G; 96.9% SS; 55.4% COD
Biodiesel wastewater	Applied voltage 18.2 V, pH 6.06, 23.5 min	55.43% COD; 98.42% O&G; 96.59% SS
Industrial oily wastewater	Current density 19.40 mA/cm^2, energy consumption 0.167 $KWhm^{-3}$	99.71% oil
Oily bilge wastewater	Current density 1.5 mA/cm^2, 60-90 min	93 ± 3.3% BOD; 78.1 ± 0.1% COD, 95.6 ± 0.2% O&G
Oily bilge wastewater	Current density 12.8 mA/cm^2, reaction temperature 32℃	99.2% COD; 93.2% O&G; 91.1% turbidity
Petroleum refinery wastewater	Current density 9 mA/cm^2, pH 8.0, time 4 min	87% COD; 90%TSS
Petroleum-contaminated wastewater	Current density 18 mA/cm^2, pH 7.0	95% TPH
Refinery oil wastewater	Current density 23.6 mA/cm^2, time 120 min	97% phenol

Oily wastewater type	Operation condition	Treatment effect
Petrochemical wastewater	Current density 21.64 mA/cm^2, NaCl concentration 2 g/L, 30 min	97.43% turbidity
Raw oily wastewater	Current density 12-16 mA/cm^2, 5-20 min	98.8% SS; 90% COD; > 80% O&G
Synthetic oil-water emulsion	Current density 25 mA/cm^2, < 22 min	90% COD

Source: [4]

3.3 Technology of Adsorption Treatment

Adsorption is the combination treatment between chemical, physical and adsorption is a physical, chemical, and electrostatic pollutants adhesion to the surface [13]. The resulting substance from the liquid phase at the interface is called the adsorbate, while the gas, solid, liquid phase where the adsorbate collects is called the adsorbent. there are some of the absorbents that are commonly used such as activated doshi, alum, carbon, chitosan zeolite, polypropylene, biosorbents, activated bentonite [4].

Table 3. Efficiency of adsorption treatment technology

Oily wastewater type	Adsorbent	Treatment effect
Oil-water emulsion	Zeolite, diatomite, bentonite, natural oil	90% COD
Palm oil mill effluent	Chitosan	99% residual oil
Palm oil mill effluent	Synthetic rubber powder	88% residual oil
Palm oil mill effluent	Oil palm waste	83.74% oil
Synthetic oily wastewater	Barley straw	90% oil
Vegetable oil mill effluent	Crab shell chitosan	74% COD; 70% TSS; 56% EC; 92% turbidity

Source: [4]

Based on the effectiveness, for removal of inorganic pollutants or organic pollutants, the adsorption process is one of the effective techniques. Not only that, it is used because of the relatively low cost [14].

3.4 Technology of Combination Treatment

Due to the complex composition of wastewater contaminated with oil, moreover, with the one method that still lacks the ability or cannot be recover free-floating, emulsion, or dispersed oil from wastewater contaminated with high strength oil, it is necessary to use combined technology to efficiently remove harmful pollutants from wastewater [8]. Combination technology combines various treatment technologies for a more effective remediation process [15].

Table 4. Combination treatment

Oily wastewater type	Combined technology	Removal efficiency
Bilge wastewater	EC and nanofiltration	52% COD; 74% COD (after EC-nanofiltration process)
Oilfield produced water	Reverse osmosis and adsorption	92% TOC
Oilfield produced water	Membrane (SBR) and membrane (SBR)/reverse osmosis	90.9% COD; 92% TOC; 91.5% O&G
Oily bilge wastewater	Photocatalytic reactor and ultrafiltration	> 90% hydrocarbon, > 80% TOC (after photocatalysis); > 99% hydrocarbon (after ultrafiltration)
Oily bilge wastewater	Photocatalytic oxidation and electro-Fenton oxidation	> 70% COD
Petroleum refinery wastewater	EC and fixed film aerobic bioreactor	> 88% COD and > 80% TPH; 95% COD and 98% TPH (after bioreactor treatment)

Source: [4]

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3.5 Technology of Microbial Bioremediation

Bioremediation is defined as a treatment that uses microorganisms in the wastewater processes. Actually, this is one of the newest emerging technologies to remove oily wastewater- a dangerous pollutant, the process can be under anaerobic conditions, or even aerobic, which as mentioned earlier it utilizes microorganisms metabolic processes, through sequestration or complete degradation. Because the pollutants that exist on wastewater are used by microbes as the source of carbon and the microbes convert them through suitable metabolites secretion to become products of innocuous.

Table 5. Technology of microbial bioremediation

The type of oily wastewater	Inoculum	Effect of treatment
Wastewater from synthetic oil	*Pseudomonas sp.*	The concentration of oil = 95 ± 1.5%
Mill olive wastewater	*Geotrichum candidum, Trichosporon cutaneum*	*Trichosporon cutaneum* (phenolic compound) = 64%, Percentage of COD = 88%, *Geotrichum candicandidum* (color) = 47%
Wastewater from oil field	*Polyammoniacum-immobilized* B350, B350M	The concentration of oil by B350 = 86%, TOC = 64%, the concentration of oil by B350M = 94% and TOC = 78%
Wastewater from the processing of olive oil mill	ATCC 20,255 *Yarrowia lipolytica*	The concentration of COD = 90%, the concentration of oil = 80%
Wastewater from engine oil	*Ochrobactrum sp.* C1	The concentration of oil = 57% oil
Wastewater from food processing, and wastewater from electronic Industry and POME	(KF049214) *Aeromonas hydrophila*, (EU555434) *Serratia marcescens*, (EU555434) *Bacillus cereus*	The concentration of oil & gas by *Serratia marcescens* = 91%, the concentration of oil & Gas by Bacillus cereus = 100% , the concentration of oil & Gas by Aeromonas hydrophila = 100%

Source: [16]

There are some kinds of parameters that the microbial depends on, such as redox potential, temperature, oxygen availability (present or absence), pH, moisture, toxic elements, the organic contents and retention times. Actually, nowadays bioremediation is one of the preferred methods for threatening the oily wastewater, because when compared with another Bioremediation, it has more eco-friendliness, low cost, and sustainability reasons. But, the negative sides of biological treatment, these methods are hard to remove sludge, long duration for treating it and it needs a large amount of land usage [16].

4. Conclusion

Treatment strategies for oil removal from wastewater are really important to know and comprehend as the steps of danger prevention when wastewater is discharged or reused. The type of treatment for removing oil from oily wastewater must be right and fulfill the standards so that it can achieve the standard level of wastewater when it will be discharged or reused by the related industry or party. There are five types of treatment can be done, such as membrane technology, technology of electrocoagulation treatment, technology of adsorption treatment, technology of combination treatment, and technology of microbial bioremediation. It is recommended to apply the methods mentioned above that are suitable with some considerations such as the case, cost, etc. Usually, for the simple cases are recommended to apply technology of microbial bioremediation, since it costs more affordable than the other methods. But, it is suggested to apply the other methods beside technology of microbial bioremediation to reach the good results. Moreover, it is important for all industries that still utilize fossil fuels or other compounds that result in oil when they are used to treat their wastewater before discharging it into the river.

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