



Characteristics, Treatment Techniques, and Operational Limitations for Refinery Wastewater: Review

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ABSTRACT

Large quantities of wastewater generate from refineries in the process of crude oil usage, distillation, and cooling systems. The wastewater samples need to be treated before disposing into the environment. Disposal of the untreated refinery wastewater causes problems for the water sources and environment. The aim of this work was to study the characteristics, treatment techniques, and limitations of refinery wastewater treatment. A number of tables were prepared to summarize and review wastewater characteristics, treatment process, and the operational limitations. Results revealed that values of some parameters such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), phenols, oil and grease, and total suspended solids (TSS) were 40.25 mg/L to 8,000 mg/L, 80 mg/L to 21,000 mg/L, 3.5 mg/L to 128 mg/L, 12.7 mg/L to 50,000 mg/L, and 22.8 to 2,580 mg/L, respectively. Numerous treatment technologies were used for the treatment of refinery wastewater. Treatment techniques have benefits, weaknesses, and operational limitations. Most amount of the TSS, oil and grease, organic materials are eliminated in the primary and secondary treatment units. Tertiary/Advanced treatment units are necessary for removal of the remaining portions of the contaminants, heavy metals, nitrogen compounds, and phosphorus. Combination of physical, chemical and biological treatment techniques increase removal efficiency of the contaminants.

1. Introduction

Petroleum consists of oil and gas. Refinery is one of the sources of producing enough quantity of wastewater that is related to the source of hydrocarbon. Refinery can be defined as storage for producing petrochemical materials from crude oil. Petrochemical materials are possibly more than 2,500 products which include kerosene, gasoline, diesel, fuel oil, liquefied gas, and oil lubrication to use in industrial for variety purpose. The consequences

of these petrochemical materials is the production of tremendous amounts of wastewater (Mustapha, 2018). The quantity and characteristics of produced wastewater are based on the configuration of the process. There is a high amount of wastewater produced during recycling of cooling water that is about 3.5-5 m³/ton. Refinery is a kind of source of producing polluting wastewater that includes chemical oxygen demand (COD), biochemical oxygen demand (BOD), oil and grease, phenol, benzene, and heavy metals (such as lead, and chrome). However,

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refinery produces soft and solid waste that ranges between 3-5 kg/ton of petrochemical. In addition, about 80 % of this waste material is considered as a hazardous due to presence of some toxic heavy metals (Benyahia et al., 2006). Modifications and novelty in the treatment of petroleum refinery wastewater have been conducted by researchers. A three-step modification including ZnO nano particle loading, UV irradiation, and Polyether sulfone coating on membranes studied by Ratman et al. (2020). Authors reported that treatment technologies increased the rejection of organic matter from 16 % to 54 %. Jafarinejad et al. (2019) stated that membrane separation was low cost and efficient for the treatment of the refinery wastewater and petrochemical plants.

Radelyuk et al. (2019) studied effluent quality of three refinery wastewater treatment plants in Kazakhstan. The authors reported that characteristics of treated wastewater exceeded the disposal standards. In another research, powdered activated carbon augmented with the sequencing batch reactor (SBR) process for improving Kawergosk oil refinery wastewater treatment in Erbil City, Kurdistan Region-Iraq was studied (Aziz and Fakhrey, 2017). Rahi et al. (2021) studied thirteen refinery wastewater treatment plants in Iraq and they stated that effluent impacted the environment and water sources. The use of Microbial Fuel Cells for simultaneous degradation of pollutants in the refinery wastewater with electricity generation was studied by Sheela (2020). Recent global issue in some developing regions and countries is a contamination of land and water by petrochemical products. Furthermore, the ecosystem is polluted by untreated refinery products released into the environment. Consequently, refinery wastewater needs treatment before disposing to natural environment. Additionally, efficiency of various treatment technologies and operational limitations for treatment of refinery wastewater are other issue.

Subsequently, the objective of this research was to describe and discuss refinery wastewater quality, various treatment techniques and studying operation limitations of petroleum refinery wastewater based on the study and results of other researchers.

1.1. Collected Data

Data were collected from published works of other researchers and arranged in Table 1 that illustrated the characteristics of refinery wastewater. Refinery wastewater contains many impurities such as BOD₅, COD, total organic carbon (TOC), phenol, oil and grease, heavy metals, pH, Turbidity, Total suspended solids (TSS) etc.

1.2. Characteristics of Refinery Wastewater

Petroleum wastewater properties are different from a refinery to another refinery and from country to country

that is based on drilling of crude oil, crude oil types, composition of crude oil and treatment strategy. It is dramatically influenced by the quantity and character of the material that causes the contamination by refinery (Aljuboury et al., 2017). Table 1 showed the different organic material types that found from petroleum. BOD refers to the quantity of organic substances in the water which causes the increase of pollution. When BOD is high then the pollution level is high. BOD is usually determined after 5 days at temperature 20 °C.

TOC represents the quantity of the organic carbon in the waste water which can be determine from the oxidation of carbonaceous (Catalytic combustion) and it measures the carbon dioxide (CO₂) production. Suspended solid is a type of the physical contamination.

The high ratio of the suspended solid makes biological alteration and aesthetic which increases the nutrients, metal quantity, fish kills and pesticide that goes in the water. Both nutrients such as nitrogen and phosphorous have the ability to make depletion of the oxygen. Ammonia (NH₃) refers to the ration of the nitrogen parts in the pollutant of the refinery wastewater that is highly harmful and toxic to the human health and aquatic life.

Other pollutants of wastewater are called heavy metals that include Iron (Fe), Copper (Cu), Cadmium (Cd), Vanadium (V), Nickel (Ni), Arsenic (As), Zinc (Zn), and Mercury (Hg). These have high ratio of toxic which leads to health problem to the human body (Abdelwahab et al., 2009). Wastewater from petroleum is composed of the pollutants composed of different organic materials and most of that material contains grease and oil which can make a barrier for oil pipes which has odors and is sticky (Mustapha, 2018). The compounds of phenolic has harmful influence to the environment because it has high toxicity and ability for long time to remain in the environment. Both sulphur and nitrogen are producing hydrogen sulphate and ammonia, respectively (Altas and Buyukgungor, 2008). The demand on the petroleum and products of petrochemical will increase fluid waste and its discharge to the water that leads to environmental pollutant (Zhao et al., 2006; Diya'uddeen et al., 2011).

The influence of this water discharge consists of toxic material accumulation, eutrophication, dissolved oxygen in to the sediment and water (Paul et al., 2021). The source contamination of drinking and ground water influences the health life in the community (Yuliwati et al., 2011). Shpiner et al. (2009) mentioned that the wastewater from petroleum included organic and inorganic materials. The organic wastewater from petroleum had grease, oil and dispersed oil, heavy oil, aromatic hydrocarbon, and phenols. The inorganic wastewater from petroleum had, for example, heavy metals and ammonia. Therefore, there are some small quantities of metals inside the crude oil which needs to be treated with a specific tool to separate it. Furthermore, hydrocarbon contains both carbon dioxide and sulphur which needs to be cleaned before going to the market

Table 1
Characteristics of petroleum refinery wastewater by the following researchers

Locations	References										
	Sulfide (mg/L)	Fe (mg/L)	pH	TSS (mg/L)	Turbidity (NTU)	Oil and grease (mg/L)	Phenol (mg/L)	TOC (mg/L)	COD (mg/L)	BOD ₅ (mg/L)	Parameter
Sourwater refinery/ Rio de Janeiro, Brazil	-	-	8-8.5	-	22-52	12.7	98-128	-	850-1,020	570	Coelho et al. (2006)
Youbang Co., China	15-30	-	6.5-6.8	90-300	150-350	400-1,000	10-20	-	500-1,000	-	Zenga et al. (2007)
Oil recovery industry (Çorlu-Tekirdağ, Turkey)	-	-	2.5	2,580	-	1,140	-	-	21,000	8,000	Dincer et al. (2008)
A petroleum refinery located in Alexandria, Egypt	-	-	8	22.8	-	-	13	-	80-120	40.25	Abdelwahab et al. (2009)
Petrochemical industry, Singapore	-	-	7.5-10.3	130-250	10.5-159.4	40-91	-	-	330-550	-	Khaing et al. (2010)
A Malaysian National Refinery	-	-	7	-	83	240	-	398	1,343	846	Hasan et al. (2012)
petroleum refinery at Whitegate, County Cork, Ireland	-	-	7.6	105	42	946	-	-	364	-	Tony et al. (2012)
petroleum company Tabriz, Iran	-	-	7.5	110	-	-	-	-	1,120	-	Farajnezhed et al. (2012)
Petroleum refinery, Perak, Malaysia	-	-	8.48	-	-	-	-	-	7,896	3,378	Gasim et al. (2013)
Petroleum refinery, hennai, India	180	-	-	375	-	50,000	20	-	1,250	625	Ibrahim et al. (2013)
Refineries, Malaysia	-	-	6.5-9.5	-	-	-	-	-	550-1,600	-	Aljuboury et al. (2014)
Oil Refining Co. in Iran	-	-	6.7	-	-	870	-	119	-	-	Saber et al. (2014)
Refinery, Rio de Janeiro, Brazil	-	-	8.5	150	-	-	-	-	1,250	-	Vendramel et al. (2015)
Kawergosk Oil Refinery, Erbil, Iraq	-	-	6.57-9.15	400-800	201.3-354	17.36	3.5	-	485	155	Aziz and Fakhrey (2016)
Local refinery, Doha, Qatar	14.5-16	-	8.3-8.7	30-40	-	-	8-10	-	3,970-4,745	-	El-Nass et al. (2016)
Not reported	142	-	8	75	-	-	70	-	1,494	718	Jafarinejad (2017)
Centre Treatment Oil ROM, Algeria	198	390	9.5	-	0.62	-	-	-	2,150	-	Zueva et al. (2020)

marketing. The toxicity depends on many factors, such as volume, variability, and quantity of the discharge (Nwanyanwu and Abu, 2010).

Table 1 illustrated that values of some parameters such as BOD, COD, phenols, oil and grease, and TSS were 40.25 mg/L to 8,000 mg/L, 80 mg/L to 21,000 mg/L, 3.5 mg/L to 128 mg/L, 12.7 mg/L to 50,000 mg/L, and 22.8 to 2,580 mg/L, respectively. Refinery wastewater contains high concentrations of the contaminants and they exceeded the disposal standards (Aziz et al., 2020).

Direct disposal of the refinery wastewater causes problems for the people, animals, and the environment.

Consequently, proper treatment is essential for the refinery wastewater prior disposal to the environment.

2. Treatment Techniques for Refinery Wastewater

Typical wastewater treatment processes are comprised of preliminary (such as screens, comminutor, grit chamber, flow equalization), primary (like oil trap,

coagulation and flocculation, dissolved air flotation, sedimentation), secondary (biological,) and advanced (tertiary) treatment processes (Radelyuk et al., 2019; Jain et al., 2020; Rahi et al, 2021).

Different treatment techniques for the refinery wastewater is illustrated in Figure 1. There are three types of wastewater treatment from hydrocarbon which are biological, chemical, and physical. Therefore, petroleum wastewater represents a complicated problem that requires a specific technique.

The conventional method needs a several steps to treat the process. First step, consists of before treatment that includes physicochemical and mechanical treatment. Second step is a more modern treatment for previous wastewater.

Different treatment methods and the removal efficiency of the pollutants for petroleum refinery wastewater are shown in Table 2.

Details and discussion for the treatment techniques are shown in the following section.

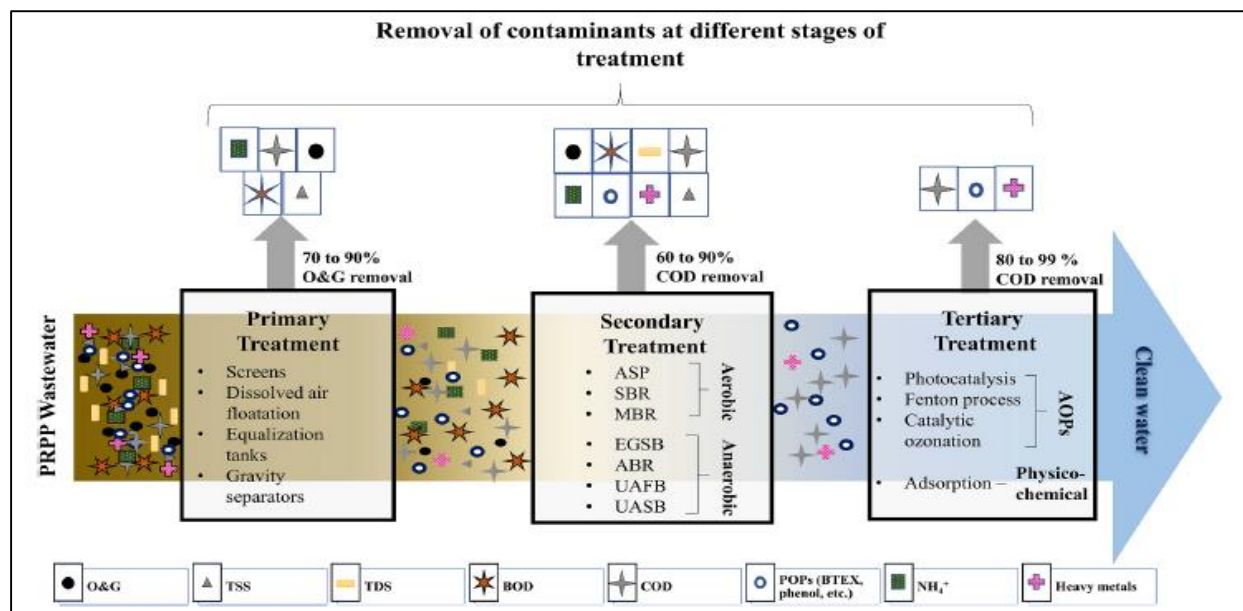


Figure 1. Different treatment methods and their target pollutants throughout the treatment of petroleum refinery wastewater (Jain et al., 2020)

Table 2
Different methods and removal efficiencies for petroleum refinery wastewater

No.	Treatment methods	Removed pollutants	Removal efficiency (%)	References
1	Aerobic biological	COD	86	Satyawali and Balakrishnan (2008)
2	Coagulation by ferric chloride	COD	52	Altaher et al. (2011)
3	Adsorption	Organic substances	62	Cavalcanti et al. (2012)
4	MBBR	Phenol	55 to 90 %	Mahmoudkhani et al. (2012)
		COD	62 to 63 %	
5	Electro-coagulation	phenol	100	El-Ashtouky et al. (2013)

Table 2 continued

Different methods and removal efficiencies for petroleum refinery wastewater

No.	Treatment methods	Removed pollutants	Removal efficiency (%)	References
6	Anaerobic biological	COD	82	Gasim et al. (2013)
7	Membrane bioreactor process	Heavy metal and iron	70 and 75	Malamis et al. (2015)
8	Physicochemical treatment	Total naphthenic acids (NAs)	16	Wang et al. (2016)
9	Activated sludge process	Naphthenic Acids (NAs)	73	Wang et al. (2016)
10	Biofilm reactor process	COD	81	Nasirpour et al. (2015)
11	Contact-stabilization process	COD	78.65 %	Ebrahimi et al. (2016)
12	Sequencing batch reactor (SBR) plus Powdered activated carbon (PAC)	Ammonia	62	Aziz and Fakhrey (2017)
		Turbidity	86	
		Electrical conductivity	42	
		Color	86	
13	Returned activated sludge plus powdered activated carbon	COD	79.05	Jafarinejad (2017)
		BOD	95.07	
		Oil and grease	95.27	
14	Constructed Wetland	COD	60-90 %	Jain et al. (2020)
		Oil	80 %	
15	Single chamber microbial fuel cells with air-cathode with additional voltage	Diesel range organics	89 %	Sheela (2020)
16	Bioelectrochemical	COD	17.84-63.10 %	Mohanakrishna et al. (2020)
17	Conventional Fenton Process	Furfural	99 %	González et al. (2021)

2.1. Physical Treatment

This treatment method is a process that is free from biological and chemical changes to treat the wastewater. Course screening is an example for removing large particle and sediment. Currently, physical technique for example sedimentation method is used for treatment to remove fine grains rather than biological method. Sedimentation method is used for separating both water and oil that is obtained. The process of changing liquid to solid state was used for reduction fine grains. Physical process was effective for treatment wastewater from petroleum due to their complexity and the other process can do better (Mikhak et al., 2019). Wang et al. (2016) reported that the maximum reductions for total naphthenic acids and aromatic naphthenic acids using physicochemical processes were 16 % and 24 %,

respectively. While in the biological process the removal efficiencies were 65 % and 86 %, respectively.

2.2. Membrane Process

According to Malamis et al. (2019) and Razavi and Miri (2015), membranes were basically divided in two main types, i.e. synthetic and biological membranes. Both ultra-filtration and electro dialysis are tools of membrane technology that are increasingly applied. This technology was found as a useful for organic matter treatment and in terms of economic efficiency it is more acceptable for treating (Jyoti et al., 2013; Kulkarni and Goswami, 2014). Razavi and Miri, (2015) showed that the average removal efficiencies of COD, BOD₅, TSS, volatile suspended solids (VSS), and turbidity using hollow fiber membrane bioreactor were obtained 82 %,

89 %, 98 %, 99 %, and 98 %, respectively. The interactions between the membrane surface and suspended solid constituents in refinery wastewater strongly influenced the membrane in polyvinylidene fluoride hollow fiber membranes, which was approved by Yuliwati et al. (2011).

2.3. Coagulation/Flocculation

This process is one of the most popular methods for treatment of wastewater to remove the material such as turbidity, COD, color, TSS (Farajnezhad and Gharbani, 2012). This treatment belongs to the pre-treatment that is used before membrane and biological treatment. This process can be also used in the final process treatment to eliminate the organic matter of non-biological origin in hydrocarbon (Farajnezhad and Gharbani, 2012). The flocculation method is used for treatment of wastewater from petroleum to bring the large removable material that includes the total phosphate, TSS, and COD. On the other hand, this process is not accurate to remove full wastewater treatment caused by level of efficiency to eliminate the organic matter (Hassan et al., 2012).

Applied the ferric chloride and aluminum chloride are used to remove wastewater from petroleum (Farajnezhad and Gharbani, 2012). They noticed that from two above parameters the aluminum chloride was more effective than ferric chloride. The changing of the pH was significant for the removal of color of the hydrocarbon while the effect of the COD was based on the properties of the petroleum and coagulant types that included metals of inorganic origin, such as ferrous sulfate and aluminum sulfate. El-Naas et al. (2009b) achieved 30 % of COD reduction at the ambient temperature, whereas at 60 °C, 53 % of COD reduction was reached.

2.4. Adsorption

The main advantages of using adsorption process are affordable cost, adaptability, and simplicity (Kulkarni & Goswami, 2013). Cavalcanti et al. (2012) studied analysis of adsorption by used organ clay for eliminating liquid waste from petroleum wastewater. They mentioned that the organophilic clay had significant effective adsorption for reducing the material with maximum toxicity for example phenols and compounds of BTEX. Technology of adsorption refers to the activated adsorption of carbon that is mainly used for ammonium, toxicity and organic compounds in petroleum treatment wastewater (Wang et al., 2007).

Activate carbon is highly influencing the reducing remain organic compounds after treatment from biological method. Therefore, pollutant of the low molecular weight is highly adsorbed (Wang et al., 2007).

This process has limited work due to consumption of

carbon activated columns (Renou et al., 2008; El-Naas et al., 2009a).

2.5. Physicochemical Treatment

Physical-chemical method is combined with previous method physical techniques for example filtration and absorption and chemical techniques for example ozonation and oxidation for treatment petroleum wastewater (El-Naas et al., 2016).

After the mechanical process, the physicochemical step collected fine grains that deposited within large grains to easily reduce by the process of floatation, sedimentation and filtration.

2.6. Chemical Treatments

This treatment consists of utilities chemical reactions to enhance the quality of water. This treatment is usually used for petroleum wastewater treatment that is called neutralization. Neutralization comprises of the base or acid to change the level of the pH. The base material is lime that is used in the neutralization of acidic waste. According to Sun et al. (2008), a microwave-catalytic wet air oxidation method gained more than 90 % of COD removal and increase in BOD₅/COD ratio at 30 min from 0.04 to 0.47 to treat petroleum wastewater at 150 °C with 0.8 MPa.

2.7. Biological Treatment

There is a number of micro-organisms used for treating wastewater to fix the last product. Part of the most micro-organisms waste is changed to water, CO₂ and other products (Zhao et al., 2006). There are several biological methods used for treating wastewater of the petroleum, for example soft reactors and biofilm reactors to eliminate organic compound pollutants (Melamane et al., 2007; Manyuchi and Ketiwa, 2013). Biological oxidation is based on the components of the wastewater from petroleum. However, this method has some disadvantage, such as high soft production and low space to COD removal (Jou and Huang, 2003). Biological process is divided into two types which are anaerobic and aerobic that depend on availability of oxygen dissolved (Zhao et al., 2006). In the anaerobic method, biochemical and chemical products reactions lead to change color and odor of the water. So, the availability of oxygen is very crucial to eliminate that process to change the odor and color (Attiogbe et al., 2007).

2.7.1. Aerobic Biological Treatment

The main objective of this process is to change organic material and refusing materials from wastewater to the

CO₂, water and biological product (Zhao et al., 2006). This type of reactor has the degradation efficiency of about 78 % and 94 % removal of the total organic carbon and oil, respectively from wastewater of the petroleum refinery. This method showed the enhancement of the COD reduction (Satyawali and Balakrishnan, 2008). Furthermore, higher willing for toxic and loads of organic shock and losing biomass was recorded.

2.7.2. Anaerobic Biological Treatment

One of the most popular methods for its economic efficiency and removal of organic component is called anaerobic biological treatment. Organic component is changed to methane (CH₄), CO₂ and wet material during this process. Due to high efficiency, this process is widely applied (Lettinga et al., 2001). The use of anaerobic up-flow of the wet beds is dramatically increased for treatment in petroleum wastewater due to simple and clear design, easy construction with highly maintenance (Rastegar et al., 2011). According to Gasim et al. (2013), the anaerobic method could easily be used for treatment of the petroleum wastewater because it could remove about 82 % of COD. Wang et al. (2016) determined that 70 % of COD was removed, as well as 72 % of the total oil which was obtained from up-flow sludge beds of anaerobic reactor for heavy oil treatment wastewater. It contained tremendous amount of the polar organic and potential efficiency for petroleum wastewater treatment. However, up-flow sludge beds of anaerobic (UASB) reactor had to be used within few organic loads and long duration time of the petroleum wastewater treatment (Wang et al., 2016). Zou (2015) illustrated that removal of NH₃-N, oil, and COD from the complex oil wastewater were 90.2 %, 86.5 %, and 90.8 %, respectively. The combinations of the UASB and biofilm reactor for treatment of the petroleum wastewater resulted in COD removal of 81.075 % (Nasirpour et al., 2015).

2.7.3. Aerated Lagoons

Biological process for the treatment of wastewater from petroleum is normally organized in wet or soft aerated lagoon environment (Tellez et al., 2002; Ma et al., 2009). The activity of being a few times aerated in lagoon does not obtain the needs in fluid treatment. They require a large area caused by small concentration of biomasses (Ma et al., 2009).

2.7.4. Activated Sludge Process

This method is compacted and it should be considerable for the area of the building tanks and other construction of the sludge. Biotransformation of the acidic naphthenic from the sludge method was mostly under effect of the temperature. The average acidic naphthenic from the

sludge during summer is higher than in the winter that is about 73 % and 53 %, respectively. It was caused by activity of the high Biotransformation microbial in the sludge system. There are some disadvantages of this method for example high amount of sludge product that needs more time and more energy (Renou et al., 2008).

2.7.5. Biofilm Reactor Process

This method has high efficiency for removing solid suspended materials (Rodgers et al., 2003; Vendramel et al., 2015). This method is known as a steady operated and flexible, with ability for difficult contaminants, and shock loads of the organic matters with large amount of the biomass existence (Galvez et al., 2003; Rodgers et al., 2003; Ibrahim et al., 2012). According to Vendramel et al. (2015), the removable amount of the COD and TSS that was about 91 % and 92 % respectively from anaerobic submerged fixed-bed reactor (ASFBR). The importance and quantity of the biofilm required more analysis in the reactor operations (Vendramel et al., 2015). The average efficiency for removing phenols in the petroleum wastewater is 98 % by utilities of the batch sequencing (Al Hashemi et al., 2015).

2.8. Summary of the Treatment Processes

Radelyuk et al. (2019) reported that the treated refinery wastewater in three treatment plants in Kazakhstan still contained surpassing concentrations of contaminants in their effluents. Rahi et al. (2021) studied effluent quality for thirteen refinery wastewaters in Iraq. The researchers stated that wastewater produced by the refineries contained high contaminants and caused problem to the people and the surrounding groundwater sources. Most suspended solids and oils, and a part of the organic matters were removed in primary treatment units. In the biological process, utmost remained parts of the organic matters are removed. For the removal of the remained organic material, nitrogen compounds, phosphorus and heavy metals further treatment techniques were required in the tertiary/advanced treatment process. Application of physical-chemical, physical-biological, and chemical-biological enhance removal efficiencies of the pollutants are needed (El-Ashtoukhy et al., 2013; Wang et al., 2016; Aziz and Fakhrey, 2017; Jafarinejad, 2017; Mohanakrishna et al., 2020; Sheela, 2020). Type of influent wastewater and the goal of the treatment decides the selection of the treatment process.

3. Limitations of Operational Parameters

Several operational parameters, laboratory and pilot plant studies were performed for the treatment of oily wastewater using aerobic and anaerobic bioreactors of various configurations and different pattern. Table 3

showed the works of other researchers for the treatment of petroleum refinery wastewater with different reactor configurations and removal efficiencies.

It can be seen from Table 3 that more than 90 % of pollutants (such as COD, hydrocarbon, oil, NH₃-N, and

turbidity) were removed in the refinery wastewater.

Commonly, the biological treatment was efficient method for refinery wastewater treated, because it contained huge amount of organic matter and hydrocarbons.

Table 3
Operational conditions and reactor configuration for petroleum refinery wastewater

Wastewater type	Treatment Technique	Operational Conditions	Parameter (Removal efficiency)	References
Petroleum refinery wastewater	Two-stage SBR	Two stage operation with Methanol as co-substrate.	COD (97.5 %)	Lee et al. (2004)
Synthetic petroleum wastewater	MSBR	HRT values of 8, 16 and 24 h.	Hydrocarbon (97 %)	Shariati et al. (2011)
Petroleum refinery wastewater	MBBR	Volume 550 L, 85 % of the reactor was filled with Polyurethane elements and MLSS 1.400-1.700 mg/L	Phenol (55 to 90 % COD- (62 to 63 %)	Mahmoudkhani et al. (2012)
Refinery wastewater	Contact-stabilization process	4.19 hr HRT, flow rate 2.77-28.8 l/day	COD (78.65 %)	Ebrahimi et al. (2016)
Heavy oil wastewater	HA-MBBR O ₃ -BAC	E _{uent} concentrations of COD, oil and ammonia were 48, 1.3 and 3.5 mg/L.	COD (95.8), Oil (98.9 %) and ammonia (94.4 %)	Zheng (2016)
Petroleum refinery wastewater	SBR plus PAC	Cycle time 6 h, PAC dosage 10 g/L, Aeration 2 L/min	Ammonia (62 %) Turbidity (86 %) Electrical conductivity (42 %) Color (86 %)	Aziz and Fakhrey (2017)
Refinery wastewater	SBR	pH 9	Oil and grease (85 %)	Qarani et al. (2020)
Oil refinery wastewater	Coagulation with central composite design	Effectiveness of Ca(OH) ₂ and Al ₂ (SO ₄) ₃	Turbidity (100 %), Total hydrocarbons (90 %) and COD (70 %)	Zueva et al. (2020)
Petroleum refinery wastewater	Single chamber microbial fuel cells with air - cathode with additional voltage	45 mWm ⁻² (control) to 12 mWm ⁻² (500mV)	Diesel range organics (89 %)	Sheela (2020)
Petroleum refinery wastewater	Bioelectrochemical	HRT 4-6 days, Voltage 330-577 mV, power density 274-832 mV/m ² , and specific power yield 0.66-2.95	COD (17.84-63.10 %)	Mohanakrishna et al. (2020)
Furfural-containing refinery wastewater	Conventional Fenton Process	Low temperature (20-40 °C), low hydrogen peroxide (< 38 g/L) and a H ₂ O ₂ /Fe ²⁺ mass ratio lower than 109	Furfural (99 %)	González et al. (2021)

In this paper review of petroleum refinery wastewater using different physical, chemical and biological methods was presented. Among them, conventional treatment technics had drawbacks as they produced large oily sludge during treatment processes. Biological treatments particularly constructed wetland were found to overcome the limitations to treat petroleum refinery

wastewater since it was not only high efficient in removing COD, phosphate, and nitrate, but also were quite efficient in the removal of phenols and other organic compounds without producing any significant amount of oily sludge (Jain et al., 2020). Each method has its advantages, disadvantages, and operation limitations.

4. Conclusion

Refinery wastewater contains huge amount of TSS, BOD, COD, oil and grease, phenols, heavy metals etc. which surpass the disposal standards. Thus, treatment is essential before disposal to the environment. Several treatment techniques were applied for the treatment of refinery wastewater. Each treatment method had its advantages, shortcomings, and operational conditions. A great part of the TSS, oil and grease, organic matters was removed in the primary and secondary treatment units. Removal of the remaining parts of the pollutants, heavy metals, nitrogen compounds, and phosphorus needed further polishing in the advanced/tertiary treatment units. Combination of physical, chemical, and biological treatment processes improves removal of pollutants.

References

- Abdelwahab O., Amin N. K., El-Ashtoukhy E-S .Z., Electrochemical removal of phenol from oil refinery wastewater, *Journal of Hazardous Materials*, 163 (2-3), 2009, 711-716,
- Al Hashemi W., Maraqa M.A., Rao M. V., Hossain M. M., Characterization and removal of phenolic compounds from condensate-oil refinery wastewater, *Desalination and Water Treatment*, 54 (3), 2015, 660-671,
- Aljuboury D .D. A., Palaniandy P., Abdul Aziz H. B., Feroz S. A, Review on the Fenton process for wastewater treatment, *Journal of Innovative Engineering*, 2 (3), 2014, 1-21,
- Aljuboury D. A. D. A., Palaniandy P., Abdul Aziz H. B., Feroz, S., Treatment of petroleum wastewater by conventional and new technologies-A review, *Global Nest Journal*, 19 (3), 2017, 439-452,
- Altaher H., El Qada E., Omar W., Pretreatment of wastewater streams from petroleum/petrochemical industries using coagulation, *Advances in Chemical Engineering and Science*, 1 (4), 2011, 245-251,
- Altas L., Buyukungor H., Sulfide removal in petroleum refinery wastewater by chemical precipitation, *Journal of Hazardous Materials*, 153, 2008, 462-469,
- Attigbe F. K., Glover-Amengor M., Nyadziehe K. T., Correlating biochemical and chemical oxygen demand of effluents, A case study of selected industries in Kumasi, Ghana, *West African Journal of Applied Ecology*, 11 (1), 2007, 110-118,
- Aziz S. Q., Fakhrey, E. S., The Effect of Kawergosk Oil Refinery Wastewater on Surrounding Water Resources, *ZANCO Journal of Pure and Applied Sciences*, Salahaddin University-Erbil, 28 (2), 2016, 656-667,
- Aziz S.Q., Fakhrey E. S., Optimization of Aeration Style and Cycle Time for Treatment of Oil Refinery Wastewater Using Powdered Activated Carbon and Sequential Batch Reactor, *ZANCO Journal of Pure and Applied Sciences*, 29 (1), 2017, 140-153,
- Aziz S. Q., Omar I. A., Bashir M. J. K., Mojiri, A., Stage by Stage design for primary, conventional activated sludge, SBR and MBBR units for residential wastewater treatment and reusing, *Advances in environmental research*, 9 (4), 2020, 233-249,
- Benyahia F., Abdulkarim M., Embaby A., Refinery wastewater treatment: A true technological challenge, 7th Annual U.A.E. University Research Conference, April 22-24. 2006, 186-194, Publisher United Arab Emirates University Reseach Affairs,
- Cavalcanti J. V. F. L., Abreu C. A. M., Carvalho M. N., Sobrinho M. A. M., Benachour M., Barauna O. S., Removal of effluent from petrochemical wastewater by adsorption using organoclay, Chapter, *Petrochemicals*, Dr Vivek Patel (Ed.), ISBN: 978-953-51-0411-7, 2012, 277-291,
- Coelho A., Castro A.V., Dezotti M., Anna G. Jr. L. S. Treatment of petroleum refinery sour water by advanced oxidation processes, *Journal of Hazardous Materials*, B, 2006, 137 (1), 178-184,
- Dincer A. R., Karakaya N., Gunes E., Gunes Y., Removal of COD from oil recovery industry wastewater by the Advanced Oxidation Processes (AOP) based on H₂O₂, *Glob. N. J.*, 10, 2008, 31-38,
- Diya'uddeen B. H., Wan M. A., Wan D., Abdul Aziz A. R. Treatment technologies for petroleum refinery effluents: A review, *Process Saf. Environ. Protec.*, 89 (2), 2011, 95-105,
- Ebrahimi M., Kazemi H., Mirbagheri S. A., Rockaway T. D., An optimized biological approach for treatment of petroleum refinery wastewater, *Journal of environmental chemical engineering*, 4 (3), 2016, 3401-3408,
- El-Ashtoukhy E-S. Z., El-Taweel Y. A., Abdelwahab O., Nassef E. M., Treatment of petrochemical wastewater containing phenolic compounds by electrocoagulation using a fixed bed electrochemical reactor, *International Journal of Electrochemical Science*, 8, 2013, 1534-1550,
- El-Naas M. H., Al-Zuhair S., Alhaija M. A., Reduction

- of COD in refinery wastewater through adsorption on Date-Pit activated carbon, *Journal of Hazardous Material*, 173 (1-3), 2009a, 750-757,
- El-Naas M. H., Al-Zuhair S., Al-Lobaney A., Makhlof S., Assessment of electro-coagulation for the treatment of petroleum refinery wastewater, *Journal of Environmental Management*, 91, 2009b, 180-185,
- El-Naas, M., Surkatti R., Al-Zuhair S., Petroleum refinery wastewater treatment: A pilot scale study, *Journal of Water Process Engineering*, 14, 2016, 71-76,
- Farajnezhad H., Gharbani P., Coagulation treatment of wastewater in petroleum industry using poly aluminum chloride and ferric chloride, *International Journal of Recent Research and Applied Studies*, 13 (1), 2012, 306-310,
- Galvez J. M., Gvmez M. A., Hontoria E., Gonzales-Lopez J., Influence of hydraulic loading and air flow rate on urban wastewater nitrogen removal with a submerged fixedfilm reactor, *Journal of Hazardous Materials*, 101 (2), 2003, 219-229,
- Gasim H. A., Kutty S. R. M., Hasnain-Isa M., Alemu L.T., Optimization of anaerobic treatment of petroleum refinery wastewater using artificial neural networks, *Research Journal of Applied Sciences, Engineering and Technology*, 6 (11), 2013, 2077-2082,
- González C., Pariente, M. I., Molina, R., Masa, M. O., Espina, L. G., Melero, J. A., Martínez F., Study of highly furfural-containing refinery wastewater streams using a conventional homogeneous Fenton process, *Journal of Environmental Chemical Engineering*, 9 (10), 2021, 104894,
- Hasan D. U. B., Abdul Aziz A. R., Daud W. M. A. W., Oxidative mineralisation of petroleum refinery effluent using Fenton-like process, *Chemical Engineering Research and Design*, 90 (2), 2012, 298-307,
- Ibrahim D., Lathalakshmi M., Muthukrishnaraj A., Balasubramanian, N., An alternative treatment process for upgrade of petroleum refinery wastewater using electrocoagulation, *Petroleum Science*, 10 (3), 2013, 421-430,
- Ibrahim H. T., Qiang H., Al-Rekabi W. S., Qiqi Y., Improvements in biofilm processes for wastewater treatment, *Pakistan Journal of Nutrition*, 11 (8), 2012, 708-734,
- Jafarnejad S., Activated sludge combined with powdered activated carbon (PACT process) for the petroleum industry wastewater treatment: A review, *Chemistry International*, 3 (4), 2017, 368-377,
- Jafarnejad S., Jiang S.C., Current technologies and future directions for treating petroleum refineries and petrochemical plants (PRPP) wastewaters, *Journal of Environmental Chemical Engineering*, 7 (5), 2019, 103326,
- Jain M., Majumder A., Ghosal P. S., Gupta, A.K., A review on treatment of petroleum refinery and petrochemical plant wastewater: a special emphasis on constructed wetlands, *Journal of Environmental Management*, 272, 2020, 111057,
- Jou Chih-Ju G., Huang Guo-Chiang, A pilot study for oil refinery wastewater treatment using a fixed film bioreactor, *Advances in Environmental Research*, 7 (2), 2003, 463-469,
- Jyoti J., Alka D., Kumar S. J. Application of membrane bio-reactor in waste-water treatment: A review, *International Journal of Chemistry and Chemical Engineering*, 3 (2), 2013, 115-122,
- Khaing T. H., Li J., Li Y., Wai N., Wong F. S., Feasibility study on petrochemical wastewater treatment and reuse using a novel submerged membrane distillation bioreactor, *Separation and Purification Technology*, 74 (1), 2010, 138-143,
- Kulkarni S. J., Goswami A. K., Adsorption studies for organic matter removal from wastewater by using bagasse Flyash in Batch and Column Operations, *Inter. J. Sci. Res.*, 2, 2013, 180-183,
- Kulkarni S. J., Goswami A .K., Applications and advancements in treatment of waste water by membrane technology: A review, *International Journal of Engineering sciences and research Technology*, 3, 2014, 446-450,
- Lee L., Hu J. Y., Ong S. L., Ng W .J., Ren J .H., Wong S. H., Two-stage SBR for treatment of oil refinery wastewater, *Water Science and Technology*, 50 (10), 2004, 243-249,
- Lettinga G., Rebac S., Zeeman G., Challenge of psychrophilic anaerobic wastewater treatment, *Trends Biotechnology*, 19 (9), 2001, 363-370,
- Ma F., Guo J., Zhao L., Chang C., Cui D., Application of bioaugmentation to improve the activate sludge system into the contact oxidation system treatment petrochemical wastewater, *Bioresource Technology*, 100 (2), 2009, 597-602,
- Mahmoudkhani R., Mokhtari Azar A., Dehghani A., Ghoreishi H., Treatment of contaminated waters with petroleum by moving bed biofilm reactor (MBBR), *International Conference on Life Science and Engineering IPCBEE*, 45, 2012, 12-16, Publisher:IACSIT Press, Singapore, ISSN: 2010-4618,
- Malamis S., Katsou E., Di Fabio S., Frison N., Cecchi F., Fatone F. Treatment of petrochemical wastewater by employing membrane bioreactors: A case study of effluents discharged to a sensitive water recipient, *Desalination and Water Treatment*, 53 (12), 2015, 3397-3406,
- Manyuchi M., Ketiwa E., Distillery effluent treatment using membrane bioreactor technology utilising pseudomonas fluorescens, *International Journal of Scientific Engineering and Technology*, 2 (12), 2013, 1252-1254,
- Melamane X. L., Strong P. J., Burgess J. E., Treatment

- of wine distillery wastewater: A review with emphasis on anaerobic membrane reactors, *South African Journal of Enology and Viticulture*, 28 (1), 2007, 25-36,
- Mikhak Y., Torabi M. M. A., Fouladitajar A., Chapter 3 - Refinery and petrochemical wastewater treatment, Title of Book: Sustainable Water and Wastewater Processing, 2019, 55-91,
- Mohanakrishna G., Abu-Reesh I. M., Pant D., Enhanced bioelectrochemical treatment of petroleum refinery wastewater with Labaneh whey as co-substrate, *Scientific Reports*, 10, 2020, 19665,
- Mustapha H. I., Treatment of petroleum refinery wastewater with constructed wetlands, (Dissertation), Wageningen University and the Academic Board of the IHE Delft, Institute for Water Education, Delft, Netherlands, 2018, 302,
- Nasirpour N., Mousavi S., Shojaosadati S., Biodegradation potential of hydrocarbons in petroleum refinery effluents using a continuous anaerobic-aerobic hybrid system, *Korean Journal of Chemical Engineering*, 32, 2015, 874-881,
- Nwyanwu C. E., Abu G. O., In vitro effects of petroleum refinery wastewater on dehydrogenase activity in marine bacterial strains, *Ambiente and Água-An Interdisciplinary Journal of Applied Science*, 5 (2), 2010, 21-29,
- Paul T., Baskaran D., Pakshirajan K., Pugazhenth G., Rajamanickam R., Bio-oil production by hydrothermal liquefaction of *Rhodococcus opacus* biomass utilizing refinery wastewater: Biomass valorization and process optimization, *Environmental Technology and Innovation*, 21, 2021, 101326,
- Qarani C.A., Barzanjy M. J., Talabany Z. J., Reducing oil pollution in Kawergosk oil refinery effluent, *Zanco Journal of Pure and Applied Sciences*, 32(5), 2020, 26-35,
- Radelyuk I., Tussupova K., Zhapargazinova K., Yelubay M., Persson M., Pitfalls of Wastewater Treatment in Oil Refinery Enterprises in Kazakhstan-A System Approach, *Sustainability*, 11 (6), 2019, 1618,
- Rahi M. N., Jaeel A. J., Abbas A. J., Treatment of petroleum refinery effluents and wastewater in Iraq: A mini review, *IOP Conference Series: Materials Science and Engineering*, 1058 (1), 2021, 012072,
- Rastegar S. O., Mousavi S. M., Shojaosadati S. A., Sheibani S., Optimization of petroleum refinery effluent treatment in a UASB reactor using response surface methodology, *Journal of Hazardous Materials*, 197, 2011, 26-32,
- Ratman I., Kusworo T.D., Utomo D. P., Azizah D. A., Ayodyasena W. A., Petroleum Refinery Wastewater Treatment using Three Steps Modified Nanohybrid Membrane Coupled with Ozonation as Integrated Pre-treatment, *Journal of Environmental Chemical Engineering*, 8 (4), 2020, 103978,
- Razavi S. M. R., Miri T., A real petroleum refinery wastewater treatment using hollow fiber membrane bioreactor (HF-MBR), *Journal of Water Process Engineering*, 8, 2015, 136-141,
- Renou S., Givaudan J. G., Poulain S., Dirassouyan F., Moulin P., Landfill leachate treatment: review and opportunity, *Journal of Hazardous Materials*, 150 (3), 2008, 468-493,
- Rodgers M., Zhan X-M., Gallagher B., A pilot plant study using a vertically moving biofilm process to treat municipal wastewater, *Bioresource Technology*, 89 (2), 2003, 139-143,
- Saber A., Hasheminejad H., Taebi A., Ghaffari G., Optimization of Fenton-based treatment of petroleum refinery wastewater with scrap iron using response surface methodology, *Applied Water Science*, 4, 2014, 283-290,
- Satyawali Y., Balakrishnan M., Wastewater treatment in molasses-based alcohol distilleries for COD and color removal: a review, *Journal Environmental Management*, 86 (3), 2008, 481-497,
- Shariati S. R. P., Bonakdarpour B., Zare N., Ashtiani, F. Z., The effect of hydraulic retention time on the performance and fouling characteristics of membrane sequencing batch reactors used for the treatment of synthetic petroleum refinery wastewater, *Bioresource Technology* 102 (17), 2011, 7692-7699,
- Sheela A. M., Petroleum Refinery Wastewater Treatment Options - Microbial Fuel Cells (MFCs) an Emerging Technology - Current Status and Future Prospects, *Recent Advances in Petrochemical Science*, 7 (1), 2020, 11-14,
- Shpiner R., Vathi S., Stuckey D. C., Treatment of oil well "produced water" by waste stabilization ponds: Removal of heavy metals, *Water research*, 43 (17), 2009, 4258-4268,
- Sun Y., Zhang Y., Quan X., Treatment of petroleum refinery wastewater by microwave-assisted catalytic wet air oxidation under low temperature and low pressure, *Separation and Purification Technology*, 62, 2008, 565-570,
- Tellez G. T., Nirmalakhandan N., Gardea-Torresdey J. L., Performance evaluation of an activated sludge system for removing petroleum hydrocarbons from oilfield produced water, *Advances in Environmental Research*, 6 (4), 2002, 455-470,
- Tony M. A., Patrick J., Purcell Yaqian Z., Oil refinery wastewater treatment using physicochemical, Fenton and Photo-Fenton oxidation processes, *Journal of Environmental Science and Health Part A-toxic/hazardous Substances and Environmental Engineering*, 47, 2012, 435-40,
- Vendramel S., Bassin J. P., Dezotti M., Sant' Anna J. G. L., Treatment of petroleum refinery wastewater containing heavily polluting substances in an aerobic submerged fixed-bed reactor, *Environmental Technology*, 36 (13-16), 2015, 2052-2059,
- Wang L. K., Hung Y. T., Lo H. H., Yapijkakis C.,

- Hazardous industrial waste treatment, CRC Press New York, USA, 2007, 526, ISBN 978-03-6739-023-5,
- Wang Y., Wang Q., Li M., Yang Y., He W., Yan G., Guo S., An alternative anaerobic treatment process for treatment of heavy oil refinery wastewater containing polar organics, *Biochemical Engineering Journal*, 105, 2016, 44-51,
- Yuliwati E., Ismail F., Matsuura T., Kassim A., Abdullah M. S., Effect of modified PVDF hollow fiber submerged ultrafiltration membrane for refinery wastewater treatment, *Desalination*, 283, 2011, 214-220,
- Zenga Y., Yang C., Zhang J., Pu W., Feasibility investigation of oily wastewater treatment by combination of zinc and PAM in coagulation/flocculation, *Journal of Hazardous Materials*, 147 (3), 2007, 991-996,
- Zhao J. H., Wang Y. M., Ye Z. F., Borthwick A. G. L., Ni J., Oil field wastewater treatment in Biological Aerated Filter by immobilized microorganisms, *Process Biochemistry*, 41 (7), 2006, 1475-1483,
- Zheng T. A., A compact process for treating oilfield wastewater by combining hydrolysis acidification, moving bed biofilm, ozonation and biologically activated carbon techniques, *Environmental Technology*, 37 (9), 2016, 1171-1178,
- Zou X., Treatment of heavy oil wastewater by UASB - BAFs using the combination of yeast and bacteria, *Environmental Technology*, 36 (18), 2015, 2381-2389,
- Zueva S., Corradini V., Ruduka E., Veglio F., Treatment of petroleum refinery wastewater by physicochemical methods, *E3S Web of Conferences*, ICEPP, 161, 2020, 01042.

Karakteristike otpadnih voda iz rafinerija, tehnike prečišćavanja i njihova ograničenja: pregled

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I Z V O D

Velike količine otpadnih voda nastaju u rafinerijama tokom postupaka prilikom kojih se koristi sirova nafta, postupka destilacije, kao i u sistemima za hlađenje. Uzorci otpadnih voda se moraju preraditi pre ispuštanja u životnu sredinu. Odlaganje neprečišćenih otpadnih voda iz rafinerija stvara probleme za izvore vode, kao i za životnu sredinu. Cilj ovog rada je bilo ispitivanje karakteristika otpadnih voda, tehnika za prečišćavanje, kao i njihovih ograničenja. Izrađen je niz tabela u kojima se rezimira i daje pregled karakteristika otpadnih voda, postupaka za prečišćavanje i operativnih ograničenja postupaka. Rezultati su pokazali da su vrednosti nekih parametara, kao što su biohemijska potreba kiseonika (BPK), hemijska potreba kiseonika (HPK), fenola, ulja i masti, kao i ukupne suspendovane supstance (TSS) redom iznosile 40,25 mg/L do 8.000 mg/L, 80 mg/L do 21.000 mg/L, 3,5 mg/L do 128 mg/L, 12,7 mg/L do 50.000 mg/L, i 22,8 do 2.580 mg/L. Prilikom prečišćavanja otpadnih voda korišćene su brojne tehnike za prečišćavanje. Svaka tehnika je pokazala svoju prednost, slabost, kao i operativno ograničenje. Većina ukupne suspendovane supstance, ulja i masti, kao i organskih materijala je bila elimisana u jedinicama za primarni i sekundarni tretman. Tercijarni/napredni postupak je bio neophodan za uklanjanje preostalih delova zagađivača, teških metala, jedinjenja azota i fosfora. Kombinacija fizičkog, hemijskog i biološkog postupka povećava efikasnost uklanjanja zagađivača.