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Recent advanced techniques in oil/water treatment

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A B S T R A C T

Nowadays in many industries, there are a huge amount of wastewater that mixed with oil particles are produced. Separation of oil particles that emulsified in oily wastewater is the basic challenge nowadays. This article review illustrates some of the conventional and advanced separation techniques that are used for separation. Separation oily wastewater using gravity and skimming, agglomeration, flotation using air, flocculation, and coagulation are all traditional oily wastewater treatment technologies that have some problems such as it is expensive in operation process, also efficiency is very weak and not effective ways, corrosive for air and land, and it leaves pollutant problems but advanced separation techniques such as separation using technology of membranes are concentrated applied for the separation of emulsified oil in wastewater in lately years as ultrafiltration membranes (UF). Generally, because of their ease of processing and low cost, also their high flexibility, polymeric membranes are critical in these processes. Many types of additives are added to a based polymer to increase it is hydrophilicity and increase it is properties as enhancing pure water flux (PWF). Additives added such as inorganic nanoparticles as titanium oxide (Tio2) which enhance flux of pure water but using pure membrane is less in pure water flux. Also adding polymeric additives to a based polymer such as polyvinyl-pyrrolidone (PVP)increase water flux and lower fouling occur. In this article review various types of separation techniques are mentioned and illustrated clearly.

1. Introduction

Water containing a considerable amount of oil, such as hydrocarbon elements and fractions of petroleum like fuel oil, kerosene, and gasoline, is known as oily wastewater [1, 2]. Many enterprises nowadays discharge a substantial amount of oily wastewater effluents into seas and rivers such as petrochemical industries and various companies such as food production, also crude oil refinery factories are examples of these industries [3]. In the fact, discharging oily wastewater with an uncontrollable method has a lot of harmful environmental influences such as ground, seas, rivers and land pollution also air pollution that result from evaporation of oil to the air and hydrocarbon content[4]. Either being toxic، petroleum hydrocarbons, polyaromatic and phenols in oily wastewater also may cause slowing down in the growth of some plants additionally it causes some diseases in body such as cancer. The size of oil particles is the main cause of devided the mixture of oil and water into three types; when particle size is larger than one hundred fifty micrometer so it called free oil and water mixtures, when particle size range from twenty and one hundred fifty micrometer so it called oil and water dispersion, and when size is less than twenty micrometer it called oil/water emulsion [5]. Among some oil/water systems, oil-in-water emulsions as small droplets have become serious environmental problem sizes (<20 μm) [6]. Numerous conventional oily wastewater treatment methods include flotation, skimming, gravity settling, coagulation, and flocculation. Although, these conventional methods are suffering from various drawbacks as the secondary pollutant and contamination are formed, energy consumed are very high, low efficiency, high running cost in operation process, corrosion, huge size of equipment, need large space requirement, and so on [7, 8] as shown in table (1). The advanced separation techniques as using waste materials such as waste bricks, natural materials such as rice straw, and membranes since membrane technology has gotten a lot of attention in the last thirty years because of its ease of use, purchase price, and lower power cost in numerous industrial domains such ultra-pure water production, water recycling, product recycling, and wastewater treatment. Due to its pore diameters (typically 2–50 nm) and capacity to extract emulsified oil droplets and other organic pollutants, ultrafiltration (UF) has been known as an impressive technology in refinery wastewater systems among many membrane technologies. [9]. Fouling, on the other hand, is a serious problem with UF membranes, and it can be produced by oil droplets closing membrane holes, resulting in severe flow reduction, or by oil layer deposition on the membrane surface. This can be caused by a variety of reasons, including membrane surface precipitation, cake layer formation, adsorption into the membrane, and closure of membrane pores [10]. Membrain can be classified into various types such as carbon Membrain can be classified into various types such as carbon membranes, ceramic membranes, and polymers membranes. In general, polymeric membranes are gambling an essential function in those techniques due to their easy, low-value processing in addition to their excessive flexibility [11]. Antifouling membranes have been developed using 3 methods: inorganic nanoparticles embedded within membrane matrix [12, 13], modification of membrane surface [14, 15] and blending of different polymers [16, 17]. Blending polymeric materials is one of the most convenient and effective strategies to improve the

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antifouling qualities and efficiency of polymeric membranes among these options since it is the most convenient way in operation and the cheapest from an economic viewpoint [18, 19]. The use of ceramic membrane technology in water treatment is rapidly expanding. Ceramic membrane technology is appealing because of its inherent advantages, such as minimal fouling tendency, chemical/thermal stability, and high durability. It looked at the latest developments in oil-water separation technologies, which are based on filtering and absorption procedures that employ a variety of materials. Figure 1 has super wetting qualities on the surface.[20]

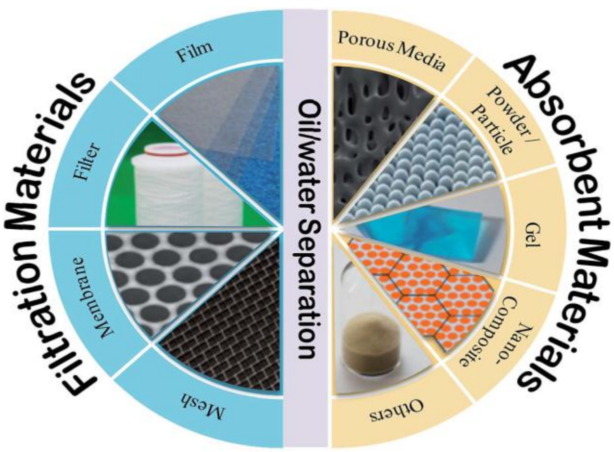

Figure1 Different materials specialized in oily wastewater treatment

2. Conventional separation technique

De emulsification, air flotation, and gravity separation and skimming, flocculation, also coagulation are all traditional oily wastewater treatment technologies that have high running costs, limited efficiency, corrosion, and recontamination which all are intrinsic problems. These various ways can remove emulsions that are classified into three types as shown in figure (2).

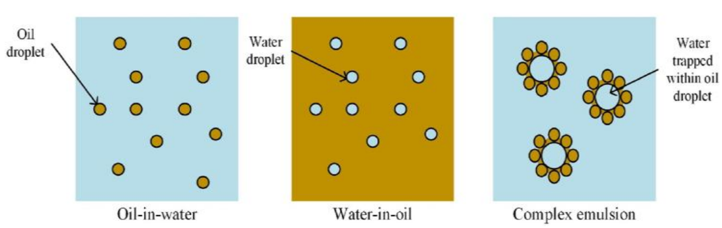

Figure 2 Different types of oil/water emulsions

2.1. Coagulation, flocculation, and air flotation (DAF) method

The most important part of oily wastewater is the breaking of the emulsified oil with two important processes coagulation and flocculation even physically, chemically, or biologically [21]. There are various types of coagulants decided according to it is chemical composition to organic coagulants, inorganic coagulants, biological coagulants, and composite coagulants. In wastewater that mixed with oils, coagulation can reduce emulsified oils, rims, suspended particles, COD, and turbidity. [22, 23]. Since utilization of the flocculant polyacrylamide (PAM), coagulants such as poly alumina iron chloride, poly alumina chloride, poly silicate alumina iron sulphate, alum, Al2(so4)3, poly ferric sulphate, and Fecl3 have had a positive effect on oil removal. [24]. Inorganic coagulant and inorganic polymer coagulant have an influence, and they are blended with polyacrylamide (PAM))[24] for treatment wastewater mixed by oils. The most important factors, namely the content of emulsified oil and dosage of coagulant and to find the optimal reaction conditions, the oily wastewater was treated at various stirring speeds, reaction periods, PH values, reaction temperature, and emulsified oil content.

2.1.1The impact of inorganic coagulant dose on oil removal.

In comparison to inorganic coagulant, inorganic polymer coagulant exhibited better demulsification effects on emulsified oil effluent, also PAF, PAC, and PSAFs achieve the best results when the dosage is slightly low. When the coagulant's demulsification capability was 500 mg/L, and the dosage was 500 mg/L so PAFC > PAC > PSAFs > alum > Al2(so4)3 > poly ferric sulfate > Fecl3. As shown in Figure (3)

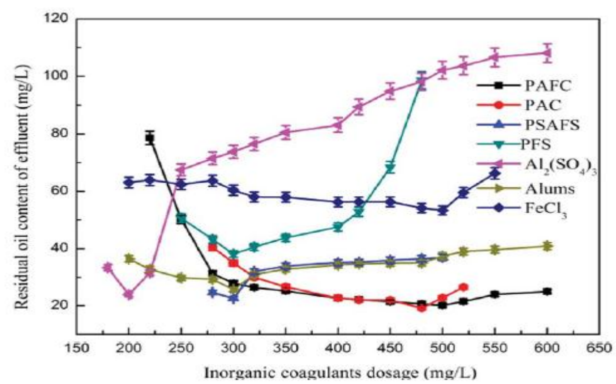

Figure 3 The influence of adding inorganic coagulant in the separation of oil and water [24]

2.1.2. The effect of inorganic coagulants and PAM dose on the separation of oil and water

PAM's interaction with an inorganic coagulant especially inorganic-polymer coagulant could minimize the amount of oil in the wastewater even more. PAM + (PAFC, PAC, PSAFs) could reach the effluent oil content of 10 mg/L as shown in figure (4).

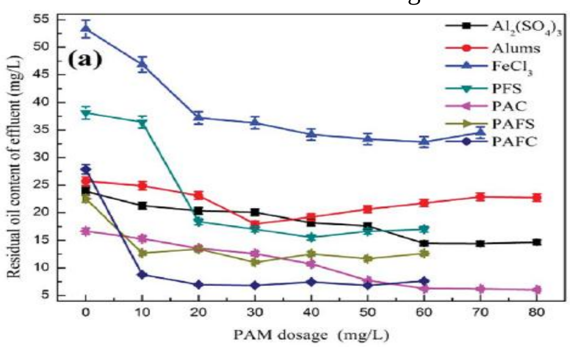

Figure 4 The influences of adding inorganic coagulants and PAM on oil/water separation [24]

2.2. Separation using electrocoagulation

Electrocoagulation is a method of removing oil from wastewater. The electrocoagulation technique, in addition to its use in municipal and industrial wastewater treatment, has the potential to treat not just surface water but also oil-contaminated groundwater. [25]. There are some advantages of the electrocoagulation process such as easy operation, requiring very basic equipment and requiring less treatment time, smaller amount of sludge, and use of fewer or no chemicals [26].

2.2.1. Mechanism of the process

"Electrolysis" gave rise to the fundamental idea of electrocoagulation. The electrolysis principle was first developed by Michael Faraday. [27]**.** It happens when direct electric current is run through an electrolyte, as shown in figure (5), causing chemical reactions at electrodes. The dissolution of the metal cations at the anode, known as the oxidation reaction, as indicated in equations, is one of the most significant chemical reactions during electrocoagulation, the anode electrode material is almost made from Al or Fe that oxidize and transfer to Al+3 or Fe+2 then releases electrons [28]. The other reduction reaction is done at the cathode as shown in equations that gain electrons and produced hydrogen gas H2 and hydroxyl ion OH-.

$$M \rightarrow M^{n+} + ne^- \quad (1)$$

$$2H_2O\ (l) + 2e^- \rightarrow 2OH^- + H_2\ (g) \quad (2)$$

$$M^{n+}\ (aq) + nOH^-\ (aq) \rightarrow M(OH)_n\ (S) \quad (3)$$

Simultaneously, hydrogen gas and hydroxyl ions are also produced with the reduction of water. The cations (Al plus3, Fe plus2, etc.) generated at the anode destabilised colloidal particles through the neutralization charges and also generated monomeric and polymeric hydroxide complex as coagulants which have high adsorption properties to collect oil particles and precipitate forming sludge. The produced H_2 bubbles at the cathode enhance the turbulence in the system and attached pollutants with it, and decreasing their relative specific weight, enhancing buoyancy, and forming flocs. Consequently, it enhances the separation process. Not only is H_2 gas used for that but also used as a fuel for producing energy [25].

2.2.2. Factors affecting the process

There are many factors affecting the process and different according to the nature of the pollutants, sources, and types of oily wastewater. Some factors affecting as pH [29], current density, reaction time, and initial pollutant concentration which is the key variables in electrochemical treatment [30].

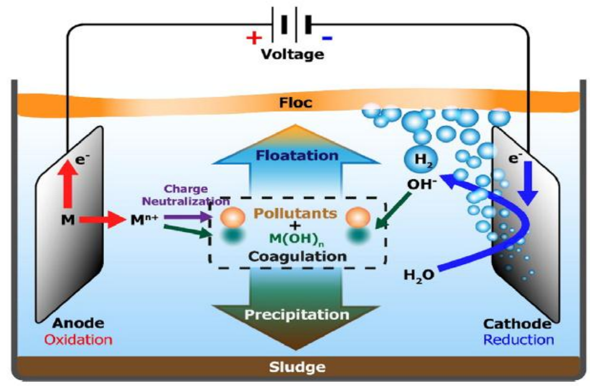

Figure 5 The electrocoagulation process' mechanism [25].

The electrochemical process' central electrode arrangement. As a result, configuration factors such as electrode spacing and electrode material are very significant. Additionally, wastewater conductivity is a crucial factor since it affects the process's current density. Last but not least, electrocoagulation is a quick and effective technique.

Table1 Comparison of various traditional techniques for separating oil from water [31]

Methods	Advantages	Disadvantages
Gravity separation	Simple design, low energy consumption	Large space requirement, slow separation rate, ineffective for the removal of submicron-sized oil droplets
Flotation	High overflow rates, easy the operation, robust and durable	Generation of large numbers of scums and sludge, the long retention time for separation
Hydrocyclones	Large treatment capacity, small volume, simple operation and	High energy requirement for generating strong centrifugal forces, low separation

	installation	efficiency for fine oil droplets, high maintenance cost
Chemical oxidation	Good oil removal efficiency, rapid destruction, easy operation	High cost for oxidizer, an undesired by-product, safety concerns associated withapplying oxidants
Biodegradation	Low operating cost, clean technology	Long retention time, wide space, sensitivity to temperature and pH variations, requirement for skilled operator

3. Advanced separation techniques

Advanced separation techniques are attractive nowadays so various article reviews are done for many topics. Advanced separation techniques such as waste materials such as waste bricks, natural materials such as rice straw, and membranes separation.

3.1. Separation using waste materials as waste bricks (WBS)

The demolition and construction (D&C) waste are representing a large part of solid waste, C&D is attracting much attention, and the economic losses and negative effects of environmental pollution have gradually widespread with the advancement of developed processes around the world [32, 33]. There are many types of demolition and construction (D &C) waste, such as bricks, aggregate, sand, and concrete. A straightforward physical procedure was successfully developed to transfer waste bricks into the WBG layer used for oil/water treatment separation utilizing the non-biodegradable waste brick (WB), which is a type of construction waste since it is a green and easy resource utilization approach. The raw material for waste brick is clay, and it is chemical composition consists of metallic oxides (such as SiO2) that are associated by water chemically and physically [34, 35]. Generally, hydroxyl groups are cover these chemical components, producing high surface energy, so that the hydrophilicity is increased [36]**.** Oil water emulsion (OWE) and water oil emulsion could be separated using the WBGs layers (WOE) using only one method which is gravity force, display high flux than traditional used membranes according to “size-sieving” mechanism.

*3.1.1. The preparation of the WBG layer*s

The WBG layer is made via an uncomplicated and straightforward physical procedure. Typically, WBs obtained from the building site were first crushed onto little granular WBs with various particle sizes. Then the second step is that the different WBGs were sieved to collect particles size of WBGs between 100 and 400 micrometer (µm). The WBG were cleaned with distilled water and then organic solvent as ethanol by ultrasonic cleaning for half-hour to eliminate contaminants, and then dried for four hours at 60 degrees Celsius. To prevent the sand WBGs from being damaged and being washed away from the liquid flow, WBGs are deposited on the surface of a stainless steel mesh under the influence of gravity, and it is then attached by another stainless steel mesh, as shown in figure (6).

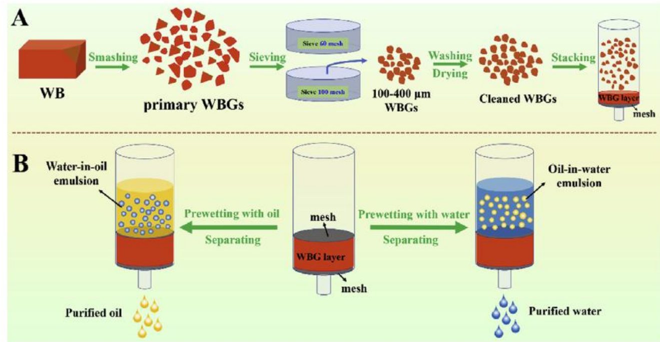

Figure 6 The preparation of green waste brick layers (A) and it is the application in oil-water treatment (B).

WBG could separate OWE or WOE since small droplets are separated even if smaller than the pore size of the WBGs layer. In WOE the oil phase adhesive onto the wetting layer then demulsification due to super oleophilic surface impelling, the water droplet repelled due to hydrophobic surface of underoil WBGs and form larger droplet leaving oil to permeate and separation done as shown in Figure (7).

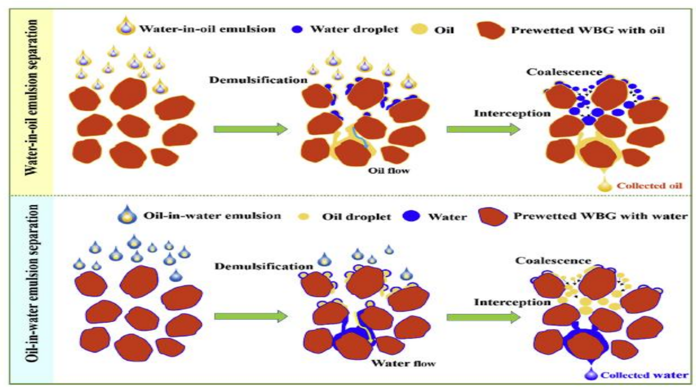

Figure 7 Oil water separation (OWE) and water oil separation (WOE) are separated using the WBG layers.

3.1.2. Separation performance

Thickness affects two factors separation filtrate flux and separation efficiency. By using different oils such as hexane, methylbenzene, trichloromethane, and soyabean oil. We determine filtrate flux for WOE and OWE conditions, and use the Karl Fischer analyzer to calculate the amount of oil or water filtrate for two conditions since Figure (8) illustrates the filtrate fluxes for OWE and WOE conditions.

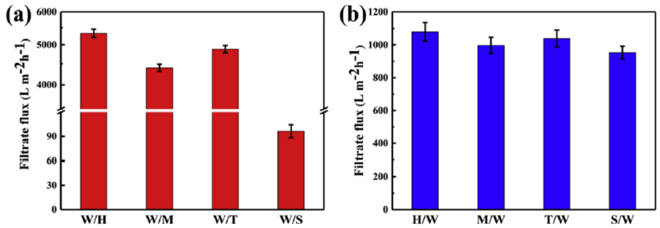

Figure 8 The diagram illustrates the filtrate fluxes versus (a)WOE and (b) OWE when the WBG layer is 3 cm thick and the solution is 10 ml in volume. [37].

For example, W/H filtrate flux decrease by increasing thickness but efficiency. the same at H/W separation as shown in figure (9).

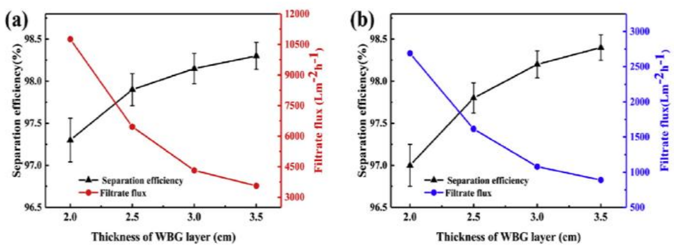

Figure 9 By increasing the WBG layer thickness, the diagram shows the separation effectiveness and filtrate flux for the W/H emulsion and the H/W emulsion, respectively. [37].

3.2. Separation using natural materials like rice straw (RS)

The rice straw is a green, widespread natural material, renewable, low cost, and friendly to the environment that has rich in hydrophilic oxygenation functional groups causing high potential for oil/water separation [38]. Rice straw (RS) was made by simple acid-base handling and a simple squeezing operation as shown in figure (10). The natural rough structure of the acid-base treatment rice straw (A1A2-RS) could not only improve the wettability of the substance but it also has holes that can adsorb emulsifiers, and the long inter-connected channels could make sure of fully completed adsorption of oil/water reaction [39].

3.2.1. Preparation of A_1A_2-RS and layer

The materials used are rice straw, H2SO4 (98%), NaOH (AR), Sodium dodecyl sulfate (SDS), organic solvents, and a CTAB emulsifier. The crude rice straw (RS) was smashed mechanically to granular particles and then passed through 60 mesh sieves. 4g of powered RS was added into H2SO4 solution 1.25% (400mL PH=1.14) with micro boiling reacting take thirty minutes. The finished product was washed with filtered water until it became neutral and is known as Acid-treated rice straw (A1-RS). When the A1-RS was added to a 1.25 percent NaOH solution (400 ml, pH=13.49) under the same conditions as boiling acid, the resulting compound, known as A1A2-RS, was created. The A1A2-RS was then cleaned with filtered water, dried for a total of twelve hours in a furnace at 60 o C, and stored. [39].

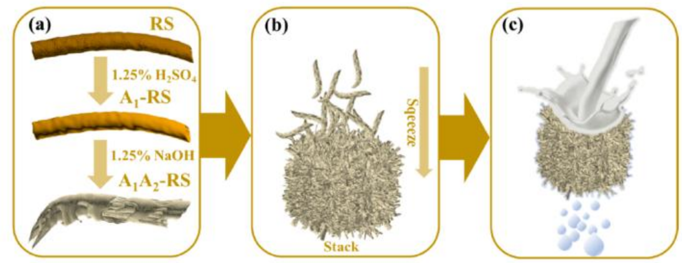

Figure 10 (a) synthesis of the A1A2-RS using a straightforward acid-base procedure; (b) Demonstrate the layer-by-layer extrusion technique. (c) the process [37]

The rice straw after treatment with acid and alkali (A_1A_2-RS) showed many humps and an evident fiber structure which is good in oily wastewater treatment**.** A table (2) showing the densities and porosities of the rice straw (RS), A2-RS, A1, A1A2, and A2A1-RS layers was created (1). Table 1 displays the cellulose, lignin, and hemicellulose component content for RS, A1-RS, A2-RS, A1A2-RS, and A2A1-RS.

Table 1 Characteristics of the different type layer (RS, A_1-RS, A_2-RS, A_1A_2-RS, A_2A_1-RS).

Layer	RS	A_1-Rs	A_2-Rs	A_1A_2-Rs	A_2A_1-Rs
Porosity	63.58	91.47	96.18	98.10	97.32
Density (g/cm^{-3})	0.20	0.16	0.12	0.12	0.12

Table 3 The composition content of lignin, hemicellulose, and cellulose in treated rice straw RS, A_1-RS, A_2-RS, A_1A_2-RS, and A_2A_1-RS.

Sample	Cellulose (%)	Lignin (%)	Hemicellulose (%)	Crude fiber (%)
Rs	28.03	20.24	9.31	57.58
A_1-Rs	41.95	13.88	10.59	66.42
A_2-Rs	47.35	10.64	11.87	69.89
A_1A_2-Rs	72.76	9.39	7.81	89.96
A_2A_1-Rs	65.83	10.27	8.25	84.35

3.2.2. Performance of RS layers in treating emulsions

The most effective layer for removing TOC is A1A2-RS. The degree of hydrophilicity and particle roughness both have a significant impact on how well filtration works. With a separation efficiency of up to 89 percent, the A1A2-RS has a significant treatment impact on the real emulsion.

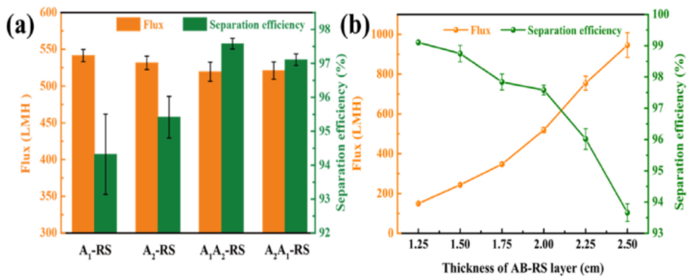

Figure 11 (a) influences of different treatments and (b) stress levels on fluxes and separation efficiencies [37].

3.3. Separation using membranes

Membranes of several kinds, including polymeric membranes and ceramic membranes, are employed in the treatment of oily wastewater. They have many advantages that overcome the disadvantages of a conventional separation techniques

3.3.1. Polymer membranes

Because of their simplicity, versatility, and affordable processing, polymer filtering membranes are essential for oil-water treatment. [11]. problems Many types of additives are added to based polymer while phase inversion is being done to enhance pure water flux (PWF) and hydrophilicity. Additives added such as inorganic nanoparticles as titanium oxide (Tio2) increase the pure water flux compared to the pure membrane. Also adding polymeric additives to based polymer increases water flux and lower fouling done for example PVC/PVP blend membranes were prepared to form flat sheets membranes using phase inversion methods since the effect of additive PVP on PVC membranes was shown by the drop in water contact angle, which went from 75 degrees to roughly 53.5 degrees and increasing the wettability. There are various types of systems for oil/water separation processes as cross-flow through the system as shown in figure (12) [41] and dead-end UF system.

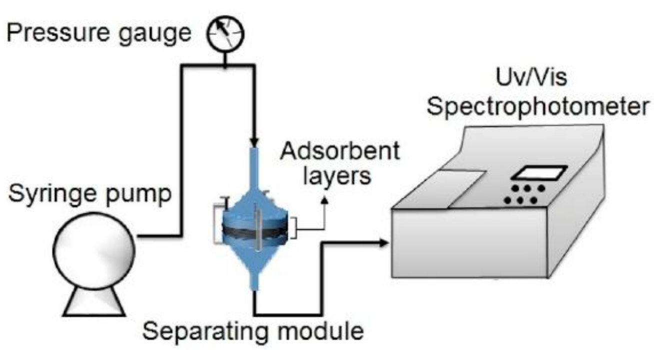

Figure The cross flow-through system.

Fabricated membranes were characterized via contact angle for prepared membranes to examine the degree of hydrophilicity by a contact angle goniometer, field emission scanning electron microscope (FESEM) to visualize the top surface and cross-section morphology of additive added to the based polymer as (PVC) and pure water flux. There are various types of based polymers and various additives that are added together to enhance the performance of membranes, based polymer as PVC that has different results according to additives added as shown in table (4).

Table 2 Modified polymeric membrane performance

Based polymer	Modification by mixed additives	Results	References
1- PVC	Adding Ag/Tio2 nanoparticles (NPs) to PVC	PWF enhanced about 43% for Ag/Tio_2/PVC	[42]
2- PVC	Blend pc to PVC	Better performance and antifouling compared to neat PVC	[43]
3- PVC	Adding Tio2 nanoparticle to PVC membrane	PWF increased by 49% compared to pure membrane	[44]
4- PVC	Diffusing Fe_2o_3 nanoparticle into casting solution	Improvement in penetration of pure water	[45]
5- PVC	Graphene oxides nanodiamond	Increase hydrophilicity, PWF, and rejection	[46]

3.3.2. Ceramic membrane

For the separation of oily wastewater in recent years, ceramic membranes have been used, because of the advantages of chemical stability, large water flux, long lifetime, and reuse again compared with the organic membranes [47, 48]. There are various literature reviews suggest the stability of the ceramic membranes which is better than polymeric membranes also the performance is better, especially when ceramic membranes were used in severe situations i.e., filtering of solvent [48-50]. Figure (13) shows the amounts of publications for researchers on the ceramic membranes from the year 2001 to 2020 and the subjects of the scientists in the last years, especially last five years [51-54]. These reviews discussed membrane performance and fabrication for oily wastewater treatment also using nanocomposite membranes for fouling control. removal of emulsified oil particles was typically the first application for ferrite-coated ceramic membranes, and it is an efficient method of treatment [55]. The market for the ceramic membranes is expected to reach an annual growth rate of about 12% [56]. However, due to high startup costs, the use of ceramic membranes in full-scale applications is currently restricted. There are attempts to create ceramic membranes using naturally occurring, inexpensive materials like kaolin. [57, 58].

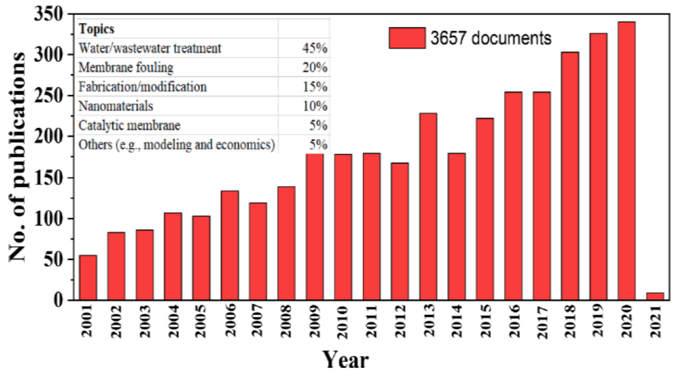

Figure 13 Number of publication from the year 2001 to 2020 and their topics in past years.

Three layers make up ceramic membranes: a thin selective layer, an intermediate layer (or layers), and a permeable supporting layer (14, a). Flat geometry (flat-sheet) with various packing densities or cylindrical arrangement are the two types of geometries that are available (namely hollow-fiber and multichannel tabular) [59] as shown (14,b). Ceramic membranes with hollow fibres and tabular shapes are excellent for use in the treatment of fatty effluent

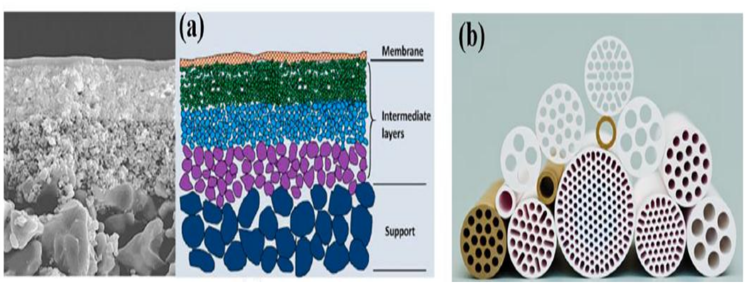

Figure 14 (a) The cross-section of ceramic membranes (b); flat sheet ceramic membrane.

3.3.3. Modification of membrains

many approaches, including the coagulation method, a coating method, and electrospinning have been developed to overcome the problems of membranes as fouling issues.

3.3.3.1. Coagulation method

The coagulation process is a convenient and effective method that has been investigated well. Various polymeric membranes applied in oily wastewater treatment has been prepared by a phase inversion process as shown in figure (15) [60]. Numerous homogenous polymers and solvent mixtures are cast into thin films or hollow fibre shapes in some studies before being submerged in a nonsolvent coagulation bath. The film with an asymmetric or a symmetric structure has been formed by the diffusional exchange of solvents and nonsolvent between the interface between the non-solvent coagulant and the solution that casted. By utilization of phase inversion process, mixing two or more certain substances which are based on polymers such as PVC, PVDF, PSF, and PES and additives that may be organic additives as polymers or inorganic additives such as Sio2, Tio2, or fe2o3 with hydrophilic and hydrophobic structures. It is possible to construct polymeric membranes that are used in the treatment of oil/water emulsions by blending materials that increase mechanical strength, thermal stability, and chemical resistance. These benefits include ease in preparing the desired qualities and tightly regulated porosity [40].

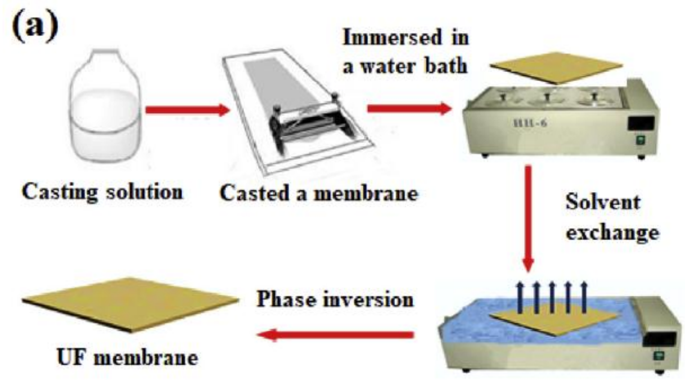

Figure 15 The schematic diagram for fabrication and enhancing UF membranes by phase inversion method

3.3.3.2. Coating methods

There are two ways of coating namely the dip-coating method and the spinning coating method for enhancing membranes. The dip coating method is a straightforward and traditional way to apply a liquid to a substrate, especially a regular thin film of liquid that will later solidify into a coating. Uniformity and Thickness can be sentient to the flow conditions in the gas overhead and the liquid bath. When the substrate is faster in withdrawn, the film deposited is thicker. For getting a uniform thin liquid film onto gradual substrates, spin coating is the most recently updated method are done of that reason. Because it can be determined that specific conditions separate thinning by a spin-off approach from further thinning and the solidification by drying, volatile solvents are the most commonly utilized methods [40].

3.3.3.3. Chemical cleaning method

Cleaning fouled membranes periodically, either manually or chemically, is a traditional way of controlling membrane fouling. For foulants that are difficult to physically remove, physical cleaning is typically combined with chemical cleaning. Oxidants, bases, acids, and surfactants are the most often utilized chemicals that have been adopted for organic foulant (in oily wastewater). These categories all employ various methods to attack the foulant.

Table 1 lists the various cleaning agents utilized in oily wastewater and their methods of removal (5).

Table 3 Various chemical cleaning agents and their removal procedures

Cleaning agent type	Common chemicals	Reaction with foulant
Base	Strong: KOH, caustic soda (NaOH) Weak: $NaHCo_3$, Na_2Co_3 EDTA	Saponification, Hydrolysis, solubilization Chelation (complexion with metals)
Acid	Strong: H_2So_4, HCl, HNo_3 Weak: Citric acid H_3Po_4	Hydrolysis, solubilization, dissolution of inorganics Chelation
Oxidant	HOCl, NaClo, H_2O_2	Oxidation of organics and disinfection
surfactants	Cationic: CTAB Anionic: SDS Nonionic: Tween 20	Surface conditioning, dispersion, and emulsifying
Enzymes	Proteases and Lipases	Catalysis of specific substrates (e.g. lipids, proteins)

3.3.4. Membrane performance

Fouling characteristics and the percentage of water flux are used to calculate membrane performance. Cross-flow filtration system almost at 1.5 bar was used to determine PWF of membranes using Equation (1) [61].

$$\bar{J}_0 = \frac{v}{A * \Delta t} \quad (1)$$

where J0 is the pure water flux (PWF; L/m2.h), t is the time (h), and v is the volume of water that has been collected (L). The membrane modulus was mounted to the oily wastewater feed tank after measuring PWF. After around three hours of membrane filtration, the flux was measured, and the modulus was reconnected to the water flux system to calculate the PWF, but after fouling (J1) at the same Equation1. The membrane was then retained in the chamber and reconnected to the water tank after the cake layer on it had been mechanically removed by a sponge and cleaned with deionized water. PWF after washing (J2) was again determined using Equation (1). The following equations were used to compute the membranes' (Jo), (J1), and (J2) fouling characteristics. [62, 63].

$$TFR = \left(\frac{\bar{J_1} - \bar{J}_0}{J_1}\right) * 100 \quad (2)$$

$$RFR = \left(\frac{\bar{J}_2 - J_0}{\bar{J_1}}\right) * 100 \quad (3)$$

$$IFR = \left(\frac{\bar{J_1} - J_2}{J_1}\right) * 100 \quad (4)$$

$$FRR = \left(\frac{J_2}{J_1}\right) * 100 \quad (5)$$

where TFR could be an add-up to fouling proportion, RFR could be a reversible fouling proportion, IFR is an irreversible fouling proportion, and FR may be a flux recuperation. These proportions are utilized to examine the anti-fouling execution of the manufactured membranes since the higher FRR values and the lower DR intended for the higher antifouling belongings of the membrane in oil/water separation performance [43]. The foremost common examination to assess treated water quality and membranes performance in the oily wastewater treatment operations is total organic carbon (TOC)[64, 65], UV spectrophotometer [61, 66], turbidity measurement[67] and chemical oxygen demand [68]. The expulsion of turbidity by the membranes was characterized as Eq.6 [69].

$$Turbidity\ removal = \left(\frac{c_f - cp}{c_f}\right) * 100 \quad (6)$$

Where C_p and C_f are the final turbidity (NTU) and initial feed turbidity (NTU) of the permeate solutions, respectively.

4- Conclusion

The most current trends have been discussed briefly in this feature piece in oily wastewater treatment technologies which have advantages and disadvantages. For next studies, a lot of technological issues and challenges still need to be resolved. First, to achieve unique surface wetting and antifouling capabilities, the majority of research have relied on both chemistry and surface roughness. Recently, many materials have been developed to achieve effective oil/water treatment as polymer membrane materials. The necessary confrontation for reaching an excellent membrane for the treatment of oily wastewater such as; (i) making these technologies simple, available on a lab-scale, and low in cost; (ii) the existence of membrane fouling caused by strong adsorption of the oil foulant on the membrane surface and pores oil droplets locked inside membrane pore structure. (iii) practical work environments including harsh physical and chemical environments. Recent studies are working on decreasing fouling in membrane treatment and how to separate much amount of oils from it is emulsions. To solve these problems, large amounts of effort and time are spent on the deep investigation process of fabrication methods and separation process.

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