REMOVAL OF OIL AND GREASE AS EMERGING POLLUTANTS OF CONCERN (EPC) IN WASTEWATER STREAM

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ABSTRACT: Wastewater characteristics, which depend on wastewater source, are increasingly becoming more toxic in recent times. The concentrations of oil and grease in wastewater streams have been observed to increase in wastewater stream with increasing adverse effects on the ecology. This results from the increasing use of oil and grease in high-demanded oil-processed foods, establishment and expansion of oil mills and refineries worldwide, as well as indiscriminate discharge of oil and grease into the water drains, domestically and industrially. This study reports the applications, efficiencies and challenges of the wastewater treatment techniques currently employed in the removal of oil and grease from the industrial wastewater and municipal water stream. The results shows that the concentrations of oil and grease injected into the ecosystem are of higher environmental impact and this needs to be given the desired attention. The desired development for effective removal of oil and grease as emerging pollutants of concern (EPC) in wastewater stream are thus proposed**.**

ABSTRAK: Ciri-ciri air sisa, bergantung kepada punca air sisa tersebut, menjadi semakin toksik akhir-akhir ini. Kepekatan minyak dan gris dalam air sisa anak sungai dilihat makin bertambah dalam air sisa anak sungai dengan bertambahnya kesan negatif ke atas ekologi. Ini disebabkan oleh peningkatan penggunaan minyak dan gris dalam makanan berproses yang tinggi permintaannya, penubuhan dan perkembangan kilang pertroleum dan loji penapisan di seluruh dunia. Minyak dan gris juga dibuang sewenang-wenangnya ke dalam parit air, dari kalangan domestik dan industry. Kajian ini membentangkan tentang aplikasi, keberkesanan dan teknik cabaran rawatan air buangan yang kini digunakan dalam pembuangan minyak dan gris dari air sisa industry dan air sungai perbandaran. Keputusan menunjukkan kepekatan minyak dan gris yang wujud dibuang ke dalam ekosistem mempunyai impak yang lebih tinggi terhadap persekitaran dan hal ini perlu diambil berat. Keinginan untuk kemajuan penyingkiran minyak dan gris sebagai keprihatinan terhadap pencemaran *(emerging pollutants of concern (EPC))*ke atas air sisa sungai dicadangkan.

KEYWORDS: *emerging pollutants of concern (EPC); oil; grease; wastewater*

1. INTRODUCTION

Oil contaminated wastewater comes from variety of sources such as crude oil production, oil refinery, petrochemical industry, metal processing, compressor condensates, lubricant and cooling agents, car washing, restaurants [1]. Oily wastewater contains toxic substances such as phenols, petroleum hydrocarbons, polyaromatic hydrocarbons, which are inhibitory to plant and animal growth, equally, mutagenic and carcinogenic to human being. Similarly, oily wastewater contains high oil content, chemical oxygen demand (COD) and colour [1]. The increase in global demand for edible oils has in the last few decades has resulted in a tremendous increase in the cultivation of oil seeds, particularly of soybean and oil palm [2]. The oil seeds are usually processed to obtain the oil contents which are subsequently processed for human consumption and industrial applications. Thus the vegetable oil industries are, equally, associated with oil extraction, refining, transportation, uses and reuses. However, these industries have been linked with environmental pollutions resulting from oil spill, oily effluent discharge into water bodies and oily sludge discharge into the environment indiscriminately, untreated or in conditions below the standard discharge limits. Oil and grease containing wastes generated from vegetable oil origin are generally classified as serious types of hazardous pollutants particularly when injected into the aquatic environments where they pose high toxicity to the aquatic organisms and other ecology damages to the water bodies [3].

Oil and grease is defined as a group of related materials rather than a specific chemical compound extractable by certain solvents, such as hexane [4, 5]. They are non-polar and, as a result, are hydrophobic in nature [5]. Generally, oil is not soluble in the water-phase and the nature of the oil-phase in oily wastewater is different from one case to another [6, 7]. Under anaerobic conditions, oils and grease hydrolyze to long chain fatty acids (LCFA) and glycerol [8, 9]. The glycerol further degrades to 1, 3-propanediol [10] and subsequently to acetate [11]. Oil-water mixture with droplets greater than or equal (≥) to 150 microns is classified as free oil while oil-water mixture with droplets size ranging between 20 and150 microns, are classified as dispersed oil mixture. Emulsified oil mixture are oil-water mixture with droplet sizes smaller than 20 microns and oil-water mixture with droplet sizes smaller than 5 microns are classified as soluble oil mixture [12].

This study focuses on wastewater containing oil and grease resulting from the extraction, refining, transportation and utilization of vegetable oil obtained from plant and animal sources except otherwise in a general form to include oil from other sources like petroleum and others.

2. VEGETABLE OIL SOURCES

The consumption of vegetable oil increased (3.5%) rapidly nearly twice more than the world population increased (1.6%) between 1980 and 2000. Predominant oil-bearing crops sourced for the production of vegetable oil include Soybean, palm, sunflower, safflower, cottonseed, rapeseed, and peanut. World major exporters of vegetable oils include Malaysia, Argentina, Indonesia, the Philippines, and Brazil while countries such as the Netherlands, Germany, the United States, and Singapore are both major exporters as well as importers of vegetable oils [13]. Countries such as China, Pakistan, Italy, and the United Kingdom are the leading world major importers of vegetable oils. Vegetable oils are generally obtained through extraction and refining processes of oils and fats from vegetable and animal sources. The initial crude oil obtained usually contains free fatty acids, phospholipids, sterols, water, odorants, and other impurities. Furthermore, refined oils and fats contain small amounts of free fatty acids and water [14]. Preliminary preparation of vegetable oil raw materials includes husking, cleaning, crushing, and conditioning after which the oil is extracted through mechanically pressing or using solvents such as hexane. The oil are carefully recovered from the extraction process through is skimming, filtration, and distillation depending on the method of extraction while the refining processes includes degumming, neutralization, bleaching, deodorization, and advanced refining process for specific demand from industries such as pharmaceutical [15].

3. SOURCES OF OIL AND GREASE IN WASTEWATER

The largest source of wastewater is produced during oil extraction processes in most oil mills and the mill effluents such as palm oil mill effluent POME may be categorized as an oily wastewater due to its high concentrations (4000 to 6000 mg/l) of oil and grease [16]. The concentration of oil and grease in an untreated domestic wastewater is always in the range between 50 to 100 mg/l [17]. Kitchen greywater is reported as the highest contributor of oil and grease in domestic greywater, though oil and grease is present in all greywater streams [18]. The presence of oil and grease has been detected in greywater, which are often designated for irrigation purposes [5, 18]. Travis et al. [5], showed that soils irrigated with greywater indicate accumulation of oil and grease up to 200 mg kg^{-1} within the first 20-cm of depth and this consequently lead to a significant reduction in the soils ability to transmit water. Some food processing industries such as slaughterhouses, dairy and meat packing industries are well known for producing effluents containing oil and grease [19-21]. Oil containing wastewater is also sourced from non-vegetable oil manufacturing industries such as the steel, machine, petroleum refining, metal cutting and metal forming, and textile industries [7]. Oily wastewater from the metalworking and finishing industries is generated from the application of coolants and lubricants used for cooling the work pieces and machine tools, reducing friction and wear of tools and dies, as well as improving the surface quality of work pieces. Industrialized countries such as United Kingdom, Italy and Germany produced large volume of such effluent [22]. The bilge water usually contains fuel oils, lubricating oils, hydraulic oils, and detergents and their concentrations largely depend on the ship type and ship-operating mode [23]. Thus, such large of amount oily wastewater has qualified oil and grease as emerging pollutants of concern (EPC) in wastewater stream.

4. ENVIRONMENTAL IMPACT OF OIL AND GREASE IN WASTEWATER

World water bodies are increasingly polluted with oily water, its effects can be irreversible for aquatic living organisms, and the consequences of these effects are transferred, indirectly or directly, to humans, as they are also involve in the in the food chain of the ecosystem. The presence of oil and grease in water bodies leads to the formation of oil layer, which causes significant pollution problem such as reduction of light penetration and photosynthesis. It further hinders oxygen transfer from atmosphere to water medium and this leads to decreased amount of dissolved oxygen (DO) at the bottom of the water and this adversely affects survival of aquatic life in water [24]. Stams and Oude [25] reported the effects of oil and grease in wastewater steam to include physical blockages in sewers, pump, screens and filter distributor arms, and these consequently lead to increase maintenance costs. These effects also include accumulation of lighter oils in the wet wells of pumping stations, fouling of electrodes or float systems which leads to pump controls failures. Where the nature of oil is highly flammable, it leads to explosion hazard in the treatment works [21]. Excessive grease in the wastewater stream causes difficulties in sludge pressing because of ‘blinding effect’ on the filter cloths [26]. Furthermore, oil and grease interfere with aerobic biological wastewater treatment processes by reducing oxygen transfer rates. Equally, oil and grease reduce the efficacy of anaerobic treatment processes by reducing the transport of soluble substrates to the bacterial biomass [27, 28]. Similarly, in the municipal water treatment plant, oil and grease cause objectionable taste and odors, turbidity and film, and make filtration treatment difficult [29].

5. TEST METHOD FOR EXTRACTION OF OIL AND GREASE IN WASTEWATER

The test procedures used to measure the concentrations of oil and grease in typical oily wastewater target only conglomerate of oily substances that are extractable by specific solvents. The American Public Health Association (APHA)'s Methods for the Examination of Water and Wastewater [30] suggested the use of the Partition-Gravimetric Method (503A) which involves the extraction of dissolved and emulsified oil and grease using trichlorotrifluoroethane. Other provisions are the Partition-Infrared Method (503B) which uses an extraction process identical to the 503A method together with Infrared Detection Methods and the Soxhlet Extraction Method (503C) which is based on an acidification of the sample, separating the oils from the liquid through filtration and extraction using trichlorotrifluoroethane. The Environmental Protection Agency (EPA), similarly favours 503A method under the General Pretreatment Regulations, 40 CFR 403.12(b) (5) (vi) for wastewater sampling and analyses.

A New ASTM Method D7066-04 is currently recommended as quick and easy field analysis method for determining oil and grease concentrations particularly for offshore oil platforms, soil remediation sites and industrial wastewater measurement. This development is due to the Montreal Protocol in 1995 banned on the use of Freon 113, which is widely employed in the ASTM method (D3921) for analyzing wastewater. The new ASTM Method D 7066–04, Standard Test Method for dimmer/trimmer of chlorotrifluoroethylene (S-316) under Recoverable Oil and Grease and Nonpolar Material by Infrared Determination, uses a similar extraction procedure with a more ozone friendly solvent called S-316. A variety of infrared instruments such as the full spectrum Fourier Transform Infrared (FTIR) spectrometers as well as portable and relatively inexpensive fixed filter infrared analyzers such as the Wilks InfraCal TOG/TPH Analyzer can be used with ASTM Method D7066-04. With the new ASTM method, options for onsite analysis of oil and grease have increased and thus lower laboratory costs, avoid out-of compliance fees, and improve remediation efficiency [31].

6. DISCHARGED REGULATIONS FOR OIL AND GREASE IN WASTEWATER

The emerging strict legislation for protection of environment demands for the application of appropriate treatment technology for the wastewater emanating from oil processing industries. The early daily allowable maximum limit for oil and grease in industrial nation such as the United State of America was 35 mg/L and the average per month was less than 17 mg/L [32]. Upward review of these regulations shifted the new maximum limit for daily allowable oil to 15 mg/L and the average per month is 12 mg/L. The Malaysian Department of Environment (DOE) has limited the standard discharge of oil and grease, particularly in palm oil mill effluents (POME), to 50 mg/L, under the current Environmental Quality Practice for the palm oil mills [33].

7. TREATMENT PROCESSES FOR OIL AND GREASE IN WASTEWATER

Oil and grease in the wastewater from oil processing industries are removed by various accepted techniques and the selection of the required equipment depends on the condition of the oil-water mixture. Some of the common conventional methods of oily wastewater treatment include flotation, gravitational methods, chemical treatment, biological treatment, dissolved air flotation (DAF) and use of membranes [34]. However, these methods are not efficient enough to treat the oily wastewater particularly when the oil are finely dispersed droplets and in dilute concentration, as well as inconsistent variations in the composition of the wastewater. Oil droplets of about 50 μm have been removed effectively by low cost equipment such as API separators, Corrugated Plate Interceptors (CPI), and Parallel Plate Interceptors (PPI), for primary treatment of oily water [35]. Oil droplets less than 50μm size have been removed by packed beds and dissolved air flotation (DAF) [36]. De-emulsification which is effective in breaking stable emulsions using chemicals such as sulphuric acid, iron and aluminum sulphate and reducing the amount of oil in the water, has not been widely embraced due to its high cost and relatively low removal efficiency [37-39]. Wastewaters containing oil and grease, derived from vegetable oils, with a significant amount of linoleic acid have been reported to be challenging to treat due to the presence and concentration of linoleic, palmitic and myristic acids produced [40]. Wastewaters containing fat and oils were traditionally treated physically, which is currently considered insufficient if the fat is in a dispersed form [41]. Abid Baig et al., [29] studied effectiveness of gravity separation and dissolved air floatation for the removal of oil and grease from industrial and domestic wastewaters and about 85% removal efficiency was achieved in removal as emulsified oil from the wastewaters.

Microbial degradation of oil wastewater involving the application of variety of microorganisms such as bacteria, molds, and yeasts, which have demonstrated effective degradability of oil-wastewater, has attracted attention in recent time [42-46]. Biological treatment of salad oil and grease from food wastewater by *Yarrowia lipolytica W29* has been studied [47]. Similarly, treatment of wastewater containing high concentrations of oil and grease matter with photosynthetic bacteria from food and agricultural wastewater has been reported in the literature [48-50]. Adsorption techniques using various adsorbents such as clay minerals have been successful in removing oil-grease from wastewater streams [24, 51, 52]. The application of membrane separation for the treatment of oily wastewater is demanded due to its high efficiency to handle a low concentration of oil. Though the use of membranes is generally hindered by membrane fouling, its economical advantage has not been that robust [53-56]. However, studies have investigated improvement and modification to obtain less fouling and higher fluxes.

Application of membrane processes using pressure as the driving force for the treatment of oily water have been applied at different locations [57-60]. The membrane technology has been integrated in some existing treatment plants to improve the quality of the treated wastewater in order to meet required limits for oil in discharged wastewaters, though it may be operated independently. Oil and grease treatment process involving aerobic biological process alone or in combination with physicochemical treatment alternatives involves high capital investments, requires skilled work force in addition to being energy intensive. In comparison, anaerobic treatment system involves low investment, omitting aeration equipment, sludge disposal facility, and recirculation and provides biogas as a fuel substitute and therefore, the system is a more viable alternative as a pretreatment facility.

The challenges militating against anaerobic treatment of wastewater containing oil and grease are the adsorption of a thin layer of oil and grease around biomass particles, which cause biomass flotation and washout. Acute toxicity of the resulting LCFA, especially unsaturated LCFA, to both methanogens and acetogens, adversely affect the application of anaerobic treatment to wastewater containing oil and grease [28, 61]. In the last few years the development of upflow anaerobic sludge blanket (UASB) concept has improved the anaerobic wastewater treatment technology and hence it wide application [62-64]. Saatci et al., [65] reported about 70% removal efficiency of total lipids (TL) and fatty acids (FA) from wastewaters of a sunflower oil factory in Turkey using upflow anaerobic sludge blanket (UASB) reactor.

Treatment of wastewaters with high oil and grease content using thermophilic treatment facilitates solubility of these contaminants in the water stream; however, it leads to fall in the sludge settleability as the temperature increases and consequently, washout of biomass and low quality effluent [66-69]. Many studies have attempted to minimize the disadvantages of this process by coupling thermophilic reactor with membrane [70, 71]. Removal efficiency (>90%) of oil and grease was obtained by Kurian and Nakhla [72] using an aerobic membrane-coupled bioreactor (MBR) operating at mesophilic-thermophilic transitional temperatures (40°C).

8. CONCLUSION

Wastewaters containing high concentration of oil and grease are increasing in volume due to the expansion in the oil processing industries worldwide. The has increased the percentage composition of oil and grease in wastewater stream, which in turn caused avert effects on the ecology and the equipment used in the treatment plants. This invariably has identified oil and grease as emerging pollutants of concern (EPC) in wastewater stream and this has opened up research opportunity in the field of wastewater treatment.

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