ATIPC – 2020 Special Issue

J. Indian Chem. Soc.,
Vol. 97, No. 12b, December 2020, pp. 2859-2863

Treatability of oily wastewater by anaerobic treatment system – A mini review

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Manuscript received online 11 December 2020, accepted 30 December 2020

With rapid industrialization and other anthropogenic activities, various toxic and inhibitory organic as well as inorganic substances enter into wastewater. This is evident from the high values of the parameters like COD, BOD, total petroleum hydrocarbon etc. The major source of oil and grease in wastewater is industrial discharge including wastewater from automobile service station. Oil and grease is considered as hazardous waste and it is very challenging task to remove it from wastewater. There are lots of methods available to remove oil and grease from wastewater. Out of these methods, biological method especially anaerobic process is found to be very effective for removing oil and grease from wastewater after pre-treatment. This review paper interprets the source, characteristics, environmental impacts and anaerobic treatment approaches for oily wastewater.

Keywords: Industrial wastewater, biological method, anaerobic treatment, oil and grease.

Introduction

Environmental pollution is seriously increasing all over the world because of rapid growth of population leading to urbanization and industrialization. There is considerable generation of wastewater every year. Sometimes, wastewater contains highly biodegradable substances, making it amenable for conventional biological treatment. However, in some cases slowly biodegradable substances like oil and grease may also present in wastewater causing inhibition to biological stabilization.

Oil and grease includes surfactant, petroleum hydrocarbon, phenolic compounds, naphthenic, fatty acid, vegetable and animal oil etc. The sources of oily wastewater are petroleum refineries, kitchens, canteens, restaurants, marine transport, workshop or garage, ball bearing manufacturing unit and different other industries[1,2].

Oil and grease is coming under the category of hazardous (Fakhrul'l-Razi *et al.,* 2009, Liu, 2004) waste which has adverse impact on both humans and nature[4,5]. Oily wastewater affects water bodies and soil by restricting oxygenation and makes waterbody aesthetically unpleasant to the aquatic species. It is also inhibitory for metabolism in living cell.

There are different methods adopted for treatment of oily wastewater such as biological, physico-chemical and combined treatment based on the characteristics and sources of wastewater. The cost of chemical methods become significant now-a-days and the handling of chemical sludge is also a difficult task. Hence, more preference should be given to biological methods for treatment of oil and grease containing wastewater as it is simple to operate and possess low cost.

Various biological treatment methods adopted so far for oily wastewater include anaerobic baffled reactor (ABR), RBC (Rotating Biological Contactor), ASP (Activated Sludge Process), upflow anaerobic sludge blanket (UASB), anaerobic filter, fixed bed reactor and sequencing batch reactor[6]. All such biological systems are found to be effective in the removal of numerous organic contaminants in dissolved form including dissolved oil. It was also reported that the utilization of facultative as well as anaerobic digestion helps in overcoming the pollution caused by the oily effluent.

The main objective of the present review paper is to investigate: (a) nature and characteristics of oil and grease containing wastewater and (b) scope of anaerobic treatment for oily wastewater.

Chronological development of anaerobic system

The use of biogas as well as the process of anaerobic digestion started in Assyria within the 10th century. Volta was the first scientist to experimentally describe the biogas production process as well as its explosive nature in presence of oxygen. In the year 1808, Sir Humphry Davy (an English scientist) experimented with straw manure and noticed that flammable gas evolve during anaerobic digestion process was actually methane, propane and hydrogen. The first biogas digester was built in Bombay, India (1859). But, the year 1930 was a pivotal moment for anaerobic digestion technology mainly for two reasons[24]. (a) The exploration of the reservoirs of natural gas pushed biogas as well as producer gas into the gloom; (b) The identification of anaerobic bacteria accountable for production of methane enhanced the spread of the technology, enabling the extensive application of the method.

Characterization of oily wastewater

Generally industrial wastewater contains high organic matter, nutrient as well as toxic substances. Wastewater contains huge amount of oil, hydrocarbon, different types of organic matters and sludge, which if discharged untreated can wreak havoc on land, water bodies and aquatic life. So, before discharging wastewater into the water bodies or on land, we have to treat it to bring the pollutants under acceptable limits. Removal of such pollutants require in depth understanding of the characteristics of oily wastewater. It is practically impossible to control all the parameters because it may make the process uneconomical. Previous research works have guided us about numerous feasible processes to remove the most harmful and toxic pollutants like oil and grease present in wastewater. The characteristics of oily wastewater coming out of different sources reported by many authors are mentioned in Table 1.

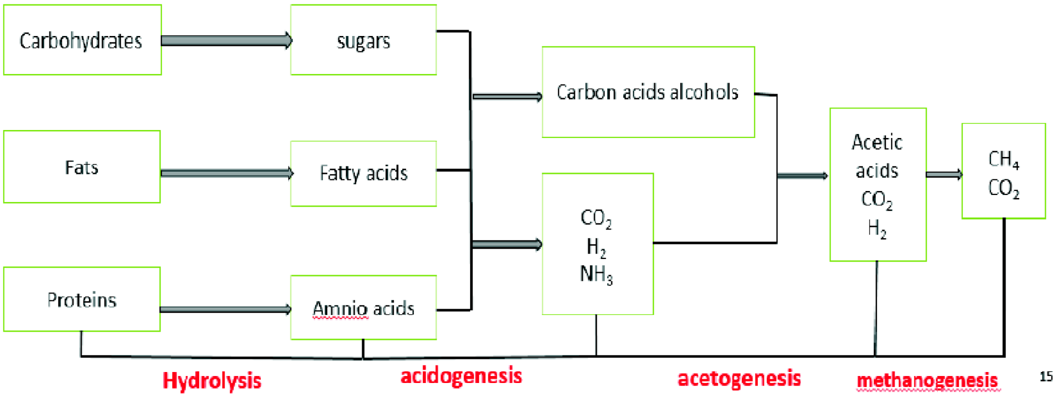
General standards for discharge of oil and grease suggested by the government of India as per Environmental Protection Rules (1986) is 10–20 mg/L and for COD is 20–250 mg/L.

Applicability and performance of anaerobic treatment

The anaerobic process differs from aerobic process in a way which occurs either in absence or in presence of extremely low amount of oxygen. This process involves four main phases i.e. (a) hydrolysis, during which complex compound is converted into simple monomeric compounds. This process has been accomplished through extracellular enzymes. Cellulose gets converted into starch, triglyceride gets converted to fatty acids using lipases. (b) The acidogenesis process converts hydrolyzed products into very simple molecules with relatively low molecular weight like volatile fatty acids, acetic acids, propionic acid, butyric acids, alcohols, aldehydes with certain gases like CO_2, NH_3 and H_2. This stage is affected by various group of bacteria that are capable of bringing down the pH inside the digester to 4. (c) In the acetogenesis phase, the products of acidogenic stage

Table 1. Characteristics of oily wastewater coming out of different sources

Sources	pH	COD (mg/L)	BOD (mg/L)	Oil and grease (mg/L)	TSS (mg/L)	Ref.
Palm oil mill effluents of P.T. (West Java)	3.3–4.6	15103-65100	8200-354000	–	–	7
Palm oil mill effluent	3.8–4.4	42500–55700	23000–26000	4900–5700	16500–19500	22
Pet food wastewater	–	18850	8820	13500	14470	20
Oil refinery wastewater after pre-treatment	6.7	373	165	291	461	19
Petrochemical wastewater	13	5360–12820	–	–	530–4146	15
Metal working fluid from industry	8.8–9.05	63000–90000	6000–7000	700	2700–3400	21



Mechanism of anaerobic treatment

are converted to acetate, H_2, and CO_2 by the acetogenic bacteria. Based on metabolism, there are two groups of acetogenic bacteria i.e. proton reducing acetogenic bacteria or H_2-forming bacteria. And acetate-oxidizing bacteria. (d) Methanogenesis is considered as the final stage of anaerobic digestion (AD) process during which the methanogens create methane from the ultimate products of acetogenesis or from a number of the intermediate products from hydrolysis and acidogenesis[16]. The anaerobic method takes place in presence of mesophilic (35–50°C) as well as thermophilic (50–60°C) cultures of microorganisms which ends up with biogas yield. The biogas obtained consists mainly of methane and carbon dioxide. The slow rate of growth of biomass, large reactor volume, and susceptibility to toxic compounds are the initial drawbacks of anaerobic bioreactors.

But new generation of reactors have been developed with small hydraulic retention time (HRT) (2 h to 48 h) with the ability to process high organic loading rates (4 to 40 kg COD/m^3 reactor per day)[17]. A very significant fact is that anaerobic reactors during start up are usually seeded with inoculum from other bioreactor. A large range of anaerobic bacteria has been reported inhabiting anaerobic fermenters. There are a lot of industrial wastewater amenable to anaerobic biotechnology. The most influencing properties are alkalinity, pH, temperature, volatile acids concentration, salinity, redox potential, small deficiency of nutrient and presence of specific cations. Changes in pH, alkalinity as well as concentration of volatile acid may affect the activity of enzyme and increase the toxicity of a variety of compounds. Ammonia inhibition on the methanogenic process is poorly understood[18].

Orhanyenigun *et al.*[23] reported that high concentration of ammonia would result in a change in methanogenic acetate utilization from direct cleavage of acetate towards the syntrophic acetate oxidation. Changes within the intracellular pH, a rise of maintenance, energy requirement with inhibition of a selected enzyme reaction were also reported. The effluent carrying chlorine-bleaching agents, surfactants as well as antibiotics is problematic for anaerobic wastewater treatment owing to its high level of toxicity for methanogenic archaea. Many of the above-described principles causing inhibition thus reduce the treatment efficiency of the anaerobic process.

Treatability of oil and grease containing wastewater

The concentration of oil and grease can be reduced by utilizing different chemical, physical as well as biological methods. Arslan-alaton *et al.* (1998) studied filtration technique for the removal of oil, grease and suspended organic matters from palm oil mill wastewater. The removal of oil and grease and suspended solid were found to be 95% and 96% respectively. Again, El-Naas *et al.*[1] studied electrocoagulation process and found 63% COD removal from petroleum refinery wastewater. There are lots of treatment methods available to treat oily wastewater like physical and chemical methods including flotation, coagulation, ultrafiltration, reverse osmosis and many more. The results of the studies on oily wastewater treatment by flotation method are mentioned in Table 2.

Table 2. Oily wastewater treatment by flotation method

Flotation type	Treatment effect	Ref.
Peeling flotation	Oil removal is 81.4%	Zheng and Zhu (2002)
Dissolved air flotation	Oil removal is more than 90%	Al-shamrani *et al.* (2003)
Dissolved air flotation	COD removal rate is 92.3%	Hamia *et al.* (2007)
Flotation	Oil removal is more than 90%	Wang (2007)

Table 3 shows the results of oily wastewater treatment by coagulation method.

Table 3. Oily wastewater treatment by coagulation

Coagulation type	Treatment effect	Ref.
Aggregation zinc silicate	Oil removal is 99%	Zhu and Zheng (2002)
CAX Coagulant	Oil removal is 98%	Lin and Wen (2003)
Poly-aluminum zinc silicate chloride	COD removal is 71.8%	Cong *et al.* (2011)

Even though the physicochemical processes remove suspended, colloidal solids and free oil, but can't remove emulsified oil which is possible only by biological treatment method. Kumar *et al.*[8] reported that the physicochemical processes are energy intensive with poor recovery efficiency and also have disposal problem. The cost of these methods are also high which include cost of chemicals, different equipment's and disposal of sludge.

The feasibility of anaerobic treatment towards oil and grease removal has been reported by different researchers. Setiadi *et al.*[7] examine the execution of anaerobic baffled reactor for the treatment of palm mill oil effluents and they have reported the removal efficiency as 64.52–82.28% for oil and grease, 41.66–86.04% for BOD and 59.6–80.50% for soluble COD.

Chunshung *et al.*[14] studied the USAB reactor for treatment of high saline wastewater obtained from heavy oil production industries. The removal of COD found to be 65.08% at HRT of more than 24 h under influent COD of (350–640) mg/L and the removal of oil was 74.33% at 112–205 mg/L of initial oil concentration. This indicated efficient treatment of heavy oil produced wastewater in UASB reactor. Shariatic *et al.*[9] studied the removal of pollutants during treatment of synthetic petroleum wastewater and the removal was found to be (12.9–54.8)% for oil and grease and (85.1–97.1)% for COD. Again, Sanghamitra *et al.*[2] studied treatment of synthetic oily wastewater by using anaerobic suspended growth reactor. The percentage removal of oil and grease and COD were obtained as 46.43–78.38% and 34.3–60.5% respectively. The efficiency of biological treatment towards oil and grease removal reported by different researchers are mentioned in Table 4.

Advantages and disadvantages of anaerobic treatment

There are certain advantages of anaerobic treatment over the aerobic treatment process. The researchers (Kobayashi *et al.*, 1983; Nebot *et al.*, 1995; Bodik *et al.*[12], Francisco Omil *et al.*, 2003) found that anaerobic filter had good load fluctuation resistance. The biggest advantage is that it produces very low quantity of sludge with very good settleablity[11] and consumes less energy. In the year of 1968, Youngs and Mc carthy found in their research that microorganism stick to support filter media so that even at high organic loading rate filter retains the bacteria. Other advantages are high efficiency of removal, simplicity of construction and operation etc. However, the anaerobic system has its own faults, for example, long start-up time due to low rate of growth of methanogenic organisms and post-treatment of anaerobic effluents required.

Table 4. Oily wastewater treatment by biological methods

Biological treatment type	Treatment effect	Ref.
Membrane bioreactor	COD removal is 97%	Fuch and Scholz (2000)
UASB	COD removal is 74%	Liu *et al.* (2003)
Biological aerated reactor	oil removal is 94	Zhao *et al.* (2003)
Yarrowialipolytica by calcium alginate	COD removal is 80–82%	Wu *et al.* (2009)
Anaerobic suspended growth reactor	Oil and grease removal is 46.43–78.38% COD removal is 34.3–60.5%	Sanghamitra *et al.* (2020)

Conclusion

The anaerobic treatment approach has long been recognized for its unique ability for converting highly objectionable wastes into useful products. Because of Global worries over energy deficiencies and ozone harming substance development through the ignition of petroleum products, more endeavours have been made towards environmentally friendly power supplies. In sewage treatment, the modelling of anaerobic digestion and obtaining higher yield of hydrogen from domestic wastewater are active research areas within the previous couple of years. Use of UASB reactor with activated sludge/sequencing batch reactor, two-stage UASB reactor/anaerobic filter/hybrid reactor, septic tank, flash aeration, use of substrate, post-treatment of UASB reactor for pathogen removal and reuse options have been studied in recent years. Modeling of anaerobic reactors for performance evaluation will be extremely needful in directing future research on anaerobic system for direct treatment of wastewater.

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