Examining options for treating oily wastewaters

By Jega Jeganathan

Food-processing industries such as meat factories, dairy industries, restaurants, vegetable oil industries, and slaughterhouses produce enormous quantities of wastewater, which are characterized by a complex combination of organic matter in either a soluble or volatile suspended form. On the other hand, substances like butter, lard, margarine and vegetable fats and oils from houses and other commercial places contribute oil and grease (O&G) to the domestic wastewater (Tchobanoglous et al., 2003).

Characteristics of oily wastewater vary considerably with the source of wastewater. However, in general, oily wastewater from the above-mentioned sources has very high chemical oxygen demand (COD) (1-200 g/L), high total suspended solids (TSS) (1-100 g/L), and high O&G (1-100 g/L).

In particular, effluent from the soybean-

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curd production process contains approximately 22 g/L of unfiltered COD, 7 g/L (as COD) of protein and 6 g/L (as COD) lipid. Relatively high concentrations of minerals (K: 451, Ca: 436, Mg: 267 mg/L) are also present in this soybean-curd wastewater (Tagawa et al., 2002).

Wool-scouring wastewater is characterized by an extremely high organic content (COD of 60–100 g/L), high lipid content (15–20 g /L) and a large proportion of solids (Becker et al., 1999). About 75% of the total organic matter is soluble; therefore, chemical and biological treatments are a suitable treatment method.

Conventional methods to treat oily wastewater have included physico-chemical processes, aerobic processes, anaerobic processes, and a combination of these processes.

Physico-chemical treatment reduces the organic load by precipitation or flotation prior to biological processes. There are several conventional physico-chemical methods: dissolved air flotation (DAF), gravity separation and skimming, membrane filtration, and coagulation and flocculation. DAF units are widely used to treat oily wastewater and to recover oil. Collected oils can either be reused or disposed of by landfill or incineration. The application of DAF for the treatment of meat-processing wastewater was studied by Wasowski (1995) with different physical parameters (amount of air, saturation pressure, recycling ratio, etc.) and different coagulants.

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It was concluded that the DAF process mainly depends on the amount of air, type of coagulant, and layout of the DAF unit. Gravity separation, followed by skimming, is another method for removing free oil from wastewater (Cheryan and Rajagopalan, 1998). These processes, however, are not effective in removing smaller oil droplets and emulsions.

Lime, aluminum sulfate, and ferric chloride could be used to break the fat emulsion and to coagulate the fat particles, which could then be removed by flotation or sedimentation (Cammarota and Freire, 2006). However, due to the cost of reagents, lower removal efficiency, and problematic sludge production, the use of the coagulation-flocculation method is not prominent.

In oily wastewater treatment, aerobic processes can biodegrade the O&G into fatty acids and then to biomass, carbon dioxide and water, thus reducing the residue. Many studies on aerobic treatment of oily wastewater have been re-

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ported (Becker et al., 1999; Tano-Debrah et al., 1999; Chiang et al., 2001; Bohdziewicz et al., 2002; Chen and Lo, 2003). Under thermophilic conditions, the change in physical properties of hydrophobic O&G made the conditions favorable for microorganisms. Becker et al. (1999) studied the biodegradation of olive oil and the treatment of the lipid-rich wool-scouring wastewater under aerobic, thermophilic (65°C) conditions and observed a severe growth inhibition when the initial olive oil concentration was increased to more than 4 g/L.

At an olive oil concentration of 2 g/L and an hydraulic retension time (HRT) of two hours, more than 90% of the O&G was removed. However, O&G removal efficiencies from wool-scouring wastewater (COD of 77 g/L and O&G of 17 g/L) were only about 20 to 30% at an HRT of 10–20 hours. Lower treatment efficiency of wool-scouring wastewater is due to its different physical and chemical properties compared to edible oils and fats such as olive oil. The high content of non-saponifiable compounds, the high degree of saturated, branched fatty acids, and the complex cyclic structure of the alcohols involved account for the poor biodegradability of wool grease compared to olive oil.

Anaerobic treatment has attracted more attention than the other treatment systems because it produces a valuable by-product, biogas, and produces less biomass. Anaerobic processes are applicable for both very high COD and very low COD wastewater. High-rate anaerobic reactors, such as upflow anaerobic sludge blanket (UASB) (Tagawa et al., 2002; Cammarota et al., 2001; Del Nery et al., 2001; Hwu et al., 1998), hybrid UASB reactors (Kim et al., 2004), and expanded granular sludge bed (EGSB) reactors (Petruy and Lettinga, 1997; Rinzema et al., 1993), are widely used for treating oily wastewaters. Treatment of complex (inhibitory/insoluble) wastewaters (e.g., containing long chain fatty acids) in high-rate reactors causes operational problems and in some cases even failure (Rinzema et al., 1989; Hwu et al., 1998).

Also, most of these studies were conducted with synthetic wastewater or low-strength wastewater with synthetically added fats to avoid the complexity and heterogeneity of O&G.

Del Poso et al. (2002) demonstrated a pilot-scale anaerobic fixed film reactor (AFFR) with vertically arranged PVC tubes as a biomass carrier for treating poultry slaughterhouse wastewater (COD of 1.4 g/L and O&G of 0.12 g/L). The experiment was conducted at low temperature (20–24°C) and the start-up period was 74 days. Efficiencies of 57% in total COD removal were obtained for an organic loading rate (OLR) of 2.7 kg COD/m^{3}d during the maturation phase, which makes the reactor an appropriate pre-treatment system for oily wastewater. Combination of UASB and rotational biological contactor (RBC) could also be used to treat oily wastewater (Wahaab and El-Awady, 1999).

In their study, anaerobic pre-treatment (UASB) followed by aerobic post-treatment (RBC) was employed for treating meat-processing wastewater (COD of 1,544 mg/L and O&G of 144 mg/L). The overall efficiency of COD, TSS, and O&G was 91.5%, 96%, and 91%, respectively. However, the levels of O&G did not comply with the regulatory discharge standards for industrial wastewater into

the sewage network.

Since acidogenic and methanogenic microorganisms require different environmental conditions, two-phase anaerobic digestion is considered to be a better option for treating oily wastewater (Ince, 1998). Specifically, high suspended solid wastewater can be degraded to volatile fatty acid (VFA) in the first reactor by hydrolytic bacteria and acid-forming bacteria and then converted into biogas by methanogens in the second reactor.

In the case of domestic wastewater treatment systems, O&G tend to clog drainpipes and sewer lines, which causes odour and sewer corrosion under anaerobic conditions. When O&G reach the municipal wastewater treatment plant in large quantities, they float as a layer on top of the water, stick onto pipes and walls, and consequently block strainers and filters. Hence the treatment efficiency of the plant declines drastically. Since O&G remain persistent during the treatment process, they end up in the sludge at the end of treatment. Their presence as a viscous and waxy ingredient makes the handling of sludge extremely difficult, in addition to greatly reducing its dewaterability (Stoll and Gupta, 1997).

As discussed previously, physico-chemical processes are usually expensive due to chemical and operating costs, along with lower removal efficiency. Moreover, current physico-chemical technologies such as flotation and sedimentation are often insufficient and extremely problematic sludges are produced when using flocculating agents like polyelectrolytes or salts (Becker et al., 1999). Also, dissolved and/or emulsified oil and grease are not retained in these units and enter into the biological treatment system, which complicates further treatment (Masse et al., 2001).

In aerobic processes, O&G have a detrimental impact on oxygen transfer by the formation of lipid coat around the floc (Chao and Yang, 1981). In particular, during activated sludge processes the amount of O&G present could be related to the occurrence of the filamentous actinomycete *Nocardia amarae* known to be involved in the formation of scum and stable foams (Becker et al., 1999).

For anaerobic biological processes, the characteristics of oily wastewater cause many challenges. Sludges with poor settling characteristics and poor activity can develop and float on the surface of the water. This may cause loss of biomass with effluent, decreasing its quantity within the reactor and decreasing the efficiency of the treatment. Furthermore, O&G adsorbed on the surface of the anaerobic sludge may limit the transport of soluble substrates to the biomass and consequently reduce the rate of substrate conversion.

Fats may solidify at lower temperatures and cause operational problems because of clogging and development of unpleasant odors (Cammarota et al., 2001). In addition, long-chain fatty acids, the primary hydrolysis products of O&G, have been demonstrated to lead to severe inhibition of the biomass (Rinzema et al., 1994) and sludge flotation/washout (Hwu, et al., 1998) in anaerobic treatment processes.

Jega Jeganathan is with R.V. Anderson Associates Limited. For more information, E-mail: jjeganathan@rvanderson.com