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Separation of pollutants from restaurant effluents as animal feed, fertilizer and renewable energy to produce high water quality in a compact area

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ABSTRACT

This paper demonstrates that oil and grease (O & G), chemical oxygen demand$_{\text{Settled}}$ (COD_S) and chemical oxygen demand$_{\text{Total-Settled}}$ ($COD_{T\text{-}S}$) levels in restaurant wastewater can be reduced to less than 50, 400 and 160 mg/L, respectively, even during busy hours (1200–1400 h), provided it is subject to chemical treatment with dissolved air flotation (DAF). After treatment the wastewater turned very clear and may be reused for various applications. The sludge generated from flotation can be recycled as an animal feed to give a mean protein content of 8.26%, a mean phosphorus level of 0.11%, and a mean calorific value of 6690 cal/g. This can be utilized as a fertilizer and a biofuel with nitrogen and phosphorus level equivalent to those of pig manure and a calorific value higher than that of wood and coal, respectively.

1. Introduction

Biological treatment of wastewater is generally agreed to be the best method [1]. However, most restaurants in Hong Kong are located in commercial buildings and it is difficult to find sufficient space to install a large biological treatment plant. Furthermore, the biodegradation rate of microbes is quite slow [2], so that the method is unsuitable to be applied in Hong Kong especially during peak hours (1200–1400 h). In fact, many commercial biochemicals, microbial cultures and enzymes are available in the market, but trials over 20 years have not given satisfactory results, especially during the peak hours. It seems that the biological method is not a practical and effective solution under the circumstances. Thus, it is important to

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find an alternative and more suitable method. Karlsson [3] has suggested that chemical precipitation provides an alternative approach to biological wastewater treatment. The former occupies less space for installation and is easier to maintain than the latter; in addition, chemical precipitation is not subject to disturbance (due to pH variation of effluent) by most industrial wastewaters and the reaction occurs quickly. Accordingly, chemical treatment is attempted here.

The Hong Kong Drainage Services Department (DSD) claimed in 2000 that more than 60% of sewer blockage was due to clogging from grease. In Hong Kong, most restaurants use grease traps (a gravity separation method) to treat their effluents. However, it has been noted that many restaurants have been prosecuted by the Environmental Protection Department (EPD) for failure to meet the conditions of their WPCO (Water Pollution Control Ordinance) licences, especially for O & G content (the highest limit is 100 mg/L). Cheremisinoff [4] pointed out that most food industry effluent contains insignificant free oil, and the gravity separation method removes little or no emulsified oil. Sokolovic et al. [5] also demonstrated that conventional gravity separation is not effective for fine oil-in-water dispersion (oil droplets $<10\ \mu m$), since most of the O & G is finely dispersed in this emulsion and cannot be separated in the grease traps (except oil droplets with a diameter $>20\ \mu m$) [4]. Alkaline detergents have been used extensively for cleaning purposes in most restaurants. They containing surfactants that emulsify free oils are present in most of the trade effluents. Most surfactants used have either anionic or non-ionic polar groups that emulsify free oil [6]. In fact, high temperature food preparation may break the oil and grease into small droplets. Furthermore, tap water used for washing is not deionised so that it carries both negative and positive charge. As a result, most of the oil becomes emulsified with water, passes through the grease trap and is discharged in the effluent. Experience over 20 years in this field revealed that this is why almost 100% of the restaurants monitored have been found to exceed their licence limit for the O & G level. Kemmer [6] claimed that the dielectric properties of water and oil cause emulsified oil droplets to carry negative charges. Hence, a cationic emulsion breaker should be used to destabilize the emulsion. Roggatz and Klute [7] managed to use a ferric salt emulsion breaker and enhanced this with DAF and pressure flotation (induced air) for O & G removal in municipal wastewater. Hence, DAF enhanced with chemicals to reduce O & G content was conducted for our compact commercial areas.

On the other hand, the Drainage Authority [8] has since 1995 set COD levels as the only criterion for assessing the water quality of all trade effluents (other than domestic and institutional type) in order to collect surcharges from the dischargers. At present, the TES (Trade Effluent Surcharge) for restaurants is HK $\$3.05/m^3$. If the COD_S (S=Settled for 1 h) content of a trade effluent discharged to a public foul sewer is less than 400 mg/L and the $COD_{T\text{-}S}$ level is also less than 160 mg/L, there is no TES. Berne and Richard [9] explained COD as representing everything that can be oxidized, particularly certain oxidizable mineral salts (sulphides, sulphites etc.) and most organic compounds while Kemmer [6] defined COD as a measure of organic matter and other reducing substances in water. It implies that COD is a measure to include O & G as well. Odegaard [10] revealed that effluents from food-processing industries contained mainly soluble organics and about 40–70% of COD were related to total suspended solids (SS). Since the turbidity of a sample for this trade effluent comes from the presence of SS and emulsified oil and the effluent arisen from the food industry is heavily loaded with these pollutants, COD can be used to evaluate its water quality.

Cassell et al. [11] and Berne and Richard [9] stated that the finer is the bubble ($\sim$50 μm and 40–70 μm, respectively), the more colloidal sized impurities will be separated from wastewater. In fact, for the design of an effective saturator for DAF system, air to solids (A/S) ratio is one of the criteria to be considered [12,13]. Many of the suspended solids in raw water sources are colloidal clay particles [14]. Berne and Richard [9] listed DAF with 20% recirculation system is the best for removal of fine suspensions and flocculated particles. DAF produces very fine bubbles [4: 10–100 μm] to form "white water" [9: water running from a tap on a high pressure main]. If "white water" is formed in the treatment system, it indicates that the operation of flotation unit is properly running.

For the mechanism of SS removal, the flotation of suspended solids is by collision of high concentration of micro-bubbles with flocs (or solid particles) of any given size [9,11,15]. Hence, the attachment of the former on the latter will promote the removal efficiency. However, large bubbles will break the flocs and generate turbulence inhibiting their floating and separating [11]. This explains why DAF is much better than induced air flotation in removing SS, O & G and hence, COD in wastewater. Thus, DAF may improve the COD removal efficiency because it generates finer bubbles (40–70 μm) than blown air flotation (100–500 μm) in water treatment [9].