

Evaluation of a laboratory-scale biological process for the treatment of edible oil effluent[#]

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Abstract

The discharge of poor quality effluents by the edible oil refining industry in South Africa is posing a serious threat to water sources and wastewater treatment installations alike. The main objective of this study was to assess the efficiency of a laboratory-scale activated sludge treatment process in producing a final effluent conforming to regulatory standards with regards to COD and phosphate loads. The study was conducted in three principal stages: waste characterisation; treatability studies and laboratory-scale investigations. After analysing various raw effluent parameters, treatability studies were conducted using an anaerobic/aerobic sequencing batch reactor (SBR). The results showed 75% influent COD (S_{in}) reduction and more than 90% removal of oils and suspended solids. Based on the results from waste characterisation and treatability studies, a continuous laboratory-scale nutrient removal system was designed. The reactor was operated on a fed-batch basis for 15 d resulting in 70% S_{in} and 4% phosphate reduction. Poor phosphorus (P) removal was attributed to a small anaerobic sludge mass fraction. The system was then operated continuously with structural changes to the reactor. A COD and phosphate reduction of 44% and a 36%, respectively, was achieved at an organic loading rate of 0.5 kgCOD/kgMLSS·d⁻¹.

Introduction

There are 16 operational edible oil processing plants in South Africa which produce approximately 3×10^5 t of vegetable oil annually, concomitantly consuming nearly 2×10^6 m³ of water. Potentially potable water entering these processing plants is either discharged to sewers or vaporised in cooling circuits (WRC, 1989). Quantity and physico-chemical characteristics of the effluents produced vary considerably for different refineries. Characteristic of the specific effluent is the high quantity of fats, oils and grease (FOG), sulphates and phosphates resulting in both high inorganic as well as organic loading of the respective wastewater treatment works.

Crude oils, particularly soybean oil, contain significant quantities of organic phosphorus in the form of phosphatides. These compounds are removed to a large extent from the oil phase in the refining process. If refinery wash waters and soap stock are acidified, P is then translocated to the water phase (Boyer, 1996). The process of edible oil refining includes neutralisation of free fatty acids, removal of gummy materials and colour and deodorising. Generally, the first three stages of refining are carried out in the same reactor as a batch process that produces a soap stock from which fatty acids are recovered by means of acid splitting. Acid splitting is carried out through addition of sulphuric acid to the soap stock which causes free fatty acids to be separated from the medium. The resulting effluent is highly acidic, with an average pH of 1.7 and average sulphate content of 4 000 mg/l (Eroglu et al., 1990; Boyer, 1996). Previous studies have shown that fatty materials within waste streams from food industries are readily biodegradable and it therefore follows that these effluents are amenable to biological treatment (Eroglu et al., 1990).

South African oil industries generally use two methods for effluent treatment: physical separation of oil and grease using dissolved air floatation (DAF) and pH control (WRC, 1997). Even after application of these methods, the remaining emulsified grease tends to clog the sewer pipes and pumps and the high COD and phosphate concentrations create shock loading problems for receiving wastewater treatment plants (Eroglu et al., 1990).

The main aim of this study was to design a laboratory-scale biological treatment process (for possible integration as an on-site remediation process) that would produce an edible oil effluent with an acceptable COD and phosphate content, in terms of regulatory standards, prior to discharge to municipal sewer systems.

Methods and materials

Wastewater characterisation

Composite wastewater samples from an edible oil refining industry situated in Pietermaritzburg (South Africa) were collected, prepared and analysed (*Standard Methods*, 1985) for parameters considered necessary for waste characterisation and system design (Table 1).

Laboratory-scale investigations

Laboratory-scale investigations were conducted in three phases. Phase 1 consisted of a semi-continuous (fed-batch) operation; during Phase 2, the system was operated on a continuous basis at high organic and phosphorus loading rates. The system was operated in a similar fashion during Phase 3 but at relatively lower organic and phosphorus loads. Based on waste characterisation studies, a 2-stage activated sludge system (alternating anaerobic/aerobic reactors) was selected to accomplish treatment. An anoxic zone was omitted from the design due to the low nitrogen content of the effluent. Operating capacities of the various zones were as follows: 1 000 m³ for the anaerobic reactor; 4 000 m³ for the aerobic reactor; and 1 800 m³ for the clarifier.

During Phase 1 of the study, the anaerobic and aerobic reactors

Revised paper. Originally presented at the WISA Conf., 28 May - 1 Jun 2000, Sun City, South Africa.

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Received 15 May 2000; accepted in revised form 4 September 2000.