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Biological treatment of fish processing wastewater: A case study from Sfax City (Southeastern Tunisia)

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ABSTRACT

The present work presents a study of the biological treatment of fish processing wastewater at salt concentration of 55 g/L. Wastewater was treated by both continuous stirred-tank reactor (CSTR) and membrane bioreactor (MBR) during 50 and 100 days, respectively. These biological processes involved salt-tolerant bacteria from natural hypersaline environments at different organic loading rates (OLRs). The phylogenetic analysis of the corresponding excised DGGE bands has demonstrated that the taxonomic affiliation of the most dominant species includes *Halomonadaceae* and *Flavobacteriaceae* families of the *Proteobacteria* (Gammaproteobacteria class) and the *Bacteroidetes* phyla, respectively. The results of MBR were better than those of CSTR in the removal of total organic carbon with efficiencies from 97.9% to 98.6%. Nevertheless, salinity with increasing OLR aggravates fouling that requires more cleaning for a membrane in MBR while leads to deterioration of sludge settleability and effluent quality in CSTR.

Introduction

In fish factories, there are different steps of fish processing such as defrosting, cleaning, cooking, and canning. Large amounts of water are required in these steps, originally for washing and cleaning purposes, and also as media for storage and refrigeration of fish product before and after processing. All these processes generate high salinity wastewater streams with a high concentration of various pollutants such as, organic matter, nutrient, and fat (Méndez et al., 1992; Intrasungkha et al., 1999; Chowdhury et al., 2010).

The high salinity organic wastewater streams can be isolated and treated separately before being discharged to the environment to keep the impact on natural ecosystems at a minimum. The biological treatment depends on the application of non-halophilic microorganisms (Woolard and Ivrine, 1995) which is normally able to tolerate a lower salt concentration up to 10 g/L without acclimatization. High salt concentrations (>10 g/L) cause disintegration of cells because of the loss of cellular water (plasmolysis) or recession of the cytoplasm which is induced by an osmotic difference across the cell wall and cause outward flow of intracellular water resulting in the loss of microbial activity and cell dehydration (Dinçer and Kargi, 2001). As a result, low removal performance of chemical and biological oxygen demands (chemical oxygen demand (COD), biochemical oxygen demand (BOD5)) and increases the effluent suspended solids (SS) especially when high salt concentrations (>20 g/L) occur (Dan et al., 2003; Liu et al., 2009). But in the case of a wastewater with a salt concentration higher than 30 g/L, the addition of halophilic or halotolerant microorganisms should be considered (Abou-elela et al., 2010). There are many types of biological systems for

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treating fish processing wastewater such as activated sludge, rotating biological contactor, aerated lagoon, anaerobic fixed filter and anaerobic digester (Chowdhury et al., 2010).

One of the effective and widely used biological treatment methods for industrial water treatment is the MBR technology, which is considered as a combination of the activated sludge process and membrane separation techniques (Artiga et al., 2008; Lay et al., 2010; Hoinkis et al., 2012). The advantages of membrane bioreactor (MBR) over conventional treatment have been thoroughly reviewed and include consistently high product quality, ease of operation and automation, reduced footprint, reduced sludge production due to a high biomass concentration in the bioreactor, and complete suspended solid removal from the effluent (Van Dijk and Roncken, 1997; Melin et al., 2006; Judd, 2011). Nevertheless, the main disadvantages of MBR are higher maintenance, operation costs and its limited performance due to fouling which constrains both operating flux and membrane life (Nuengjamnomg et al., 2005; Drews, 2010).

Around Sfax City (Southeastern Tunisia), a tuna fish canning factory discharge is characterized by a high content of salt and organic matter, at a concentration that doesn't fulfill the legal requirement for the environment protection. The aim of this work is the investigation of biological treatment of fish processing wastewater, with salt concentrations up to 5.5%, by two different methods such as MBR and continuous stirred-tank reactor (CSTR) involving salt-tolerant bacteria. Furthermore, we will focus on the efficiency of MBR method on the removal of total organic carbon (TOC), BOD, and nutrients at different organic loading rates (OLRs).

1. Materials and methods

1.1. *Reactor design and operation*

The different experimental steps were carried out for the period of 250 days. During the first 100 days (start-up period), the biomass in the bioreactor was acclimatized to saline wastewater concentration containing 5.5% and was increased by omitting sludge wastage until reaching the mixed liquor suspended solid (MLSS) concentration values, above 5 g/L. The 150 remaining days pertained to the treatment of wastewater in CSTR (50 days) and in MBR (100 days). An activated sludge process was performed in a 20 L bioreactor vessel Biolafitte (LSL Biolafitte S.A., Saint Germain en Laye, France) of a working volume of 12 L. Air was supplied using a diffuser and aeration rate was maintained constant, at 0.35 volume of air/volume of reactor/min (v.v.m), and agitation at 160 r/min. Minimum dissolved oxygen of 2–3 mg/L in the bioreactor was generally available during the experiments. Besides, the reactor temperature varied between 20 and 30°C by circulating water through the water jacket of the reactor. The flux of wastewater influent was guaranteed by peristaltic pump (Gilson Inc., Middleton, WI, USA).

The CSTR system consists of an aerated reactor and a static decanter (Fig. 1). Following the reactor, the decanter was used to separate the activated sludge from the treated wastewater. While the excess sludge is removed, the remaining part is recycled back into the reactor, thus maintaining the sludge concentration constant. The clarified effluent was then collected and analyzed. The hydraulic retention time (HRT) was fixed at 2 days; the OLR rose from 0.5 to 0.7 kg TOC/(m^3·day) during the first 10 operating days and then from day 11 onward, the OLR in the reactor was about 0.9 kg TOC/(m^3·day).

For MBR system, the external tubular unit of a cross-flow ultrafiltration membrane was used instead of the decanter under the same operating conditions of CSTR. MBR system consists of a SALMSON Pump type Multi-H 206SE-T/B and KER 40 mineral membrane: 400 mm in length, 30 mm in diameter, 0.04 m^2 in surface and of a 0.2-μm pore size (Fig. 1). The trans-membrane pressure (TMP) of the effluent was monitored by a manometer in a bar transformed from kPa. The ultrafiltration membrane was cleaned using a solution of NaOH (pH 11, 12) for 1 hr at 45°C and then by water cycle to restore a neutral pH and to maintain a favorable flow. But when the flow is not recovered, an additional cleaning using nitric acid may be useful.

During the MBR experiment, the concentrate of biomass recovered from the membrane was sent back to the reactor. The biomass was exposed to a rising of OLR from 0.5 to 1.4 kg TOC/(m^3·day) and this leads the HRT to decrease from 3.8 to 1.42 days. Before the wastewater treatment, pH was adjusted at 7 ± 1 by 2.0 mol/L of NaOH solution.

1.2. *Wastewater composition*

The studied industrial wastewater for biological treatment was generated from "Sultan tuna factory" located in Sfax City,

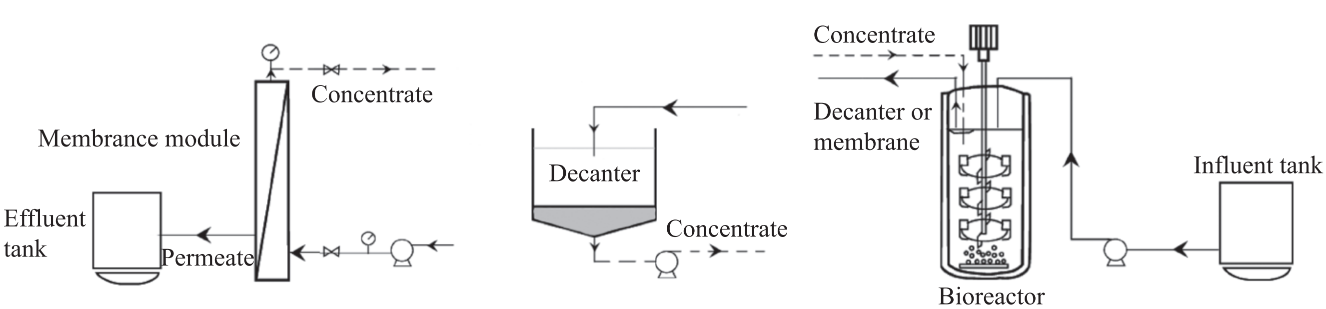

Fig. 1 – Schematic diagrams of CSRT (Bioreactor + Decanter) and MBR (Bioreactor + Membrane module). Experimental conditions: OLR (0.5–0.9 for continuous stirred-tank reactor (CSTR) and 0.5–1.4 kg TOC/(m^3·day) for MBR), salt concentration = 55 g/L, pH = 7.0 ± 0.5 and temperature 27 ± 2°C.