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Fish canning wastewater treatment by activated sludge: Application of factorial design optimization Biological treatment by activated sludge of fish canning wastewater

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ABSTRACT

The optimization of hydraulic retention time (HRT) and initial organic matter concentration for dissolved organic carbon (DOC) abatement of wastewater from a fish canning industry of northern Portugal by activated sludge was investigated using response surface methodology (RSM). The two parameters were chosen since it was found that the treatment efficiency is mainly influenced by them. The experimental data on DOC removal were fitted into a quadratic polynomial model using factorial design and RSM. The optimum process conditions were determined by analyzing the response surface of a three-dimensional plot and by solving the regression model equation. The obtained results showed a HRT of 6.4 h and an initial DOC of 406.2 mg/L as the best treatment conditions. Under these conditions, the maximum predicted DOC removal was 88.0%, confirming the feasibility and the reliability of fish canning wastewater treatment by activated sludge for organic content removal.

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1. Introduction

Portugal is a country with a long coastline (around 1800 km) and with great tradition and potential for fishing. According to data from the National Statistics Institute, in 2012, the Portuguese fleet captured more than 197,500 t of fish and nearly 44,000 tons of prepared and canned fish were manufactured, from which 27,500 t were exported. The commercial fish-processing industry generates large quantities of solid waste and wastewater [1]. The treatment of fish canning wastewater is particularly difficult due to the high content in organic matter and salt, and the characteristics of the companies, which are mainly small companies, widely dispersed and with high seasonal activity [2,3]. This sector is also known by the considerable variability in water consumption and effluent characteristics. In fact, the level of total soluble and suspended chemical oxygen demand (COD) varies largely among factories and fish type [4]. All these factors make it difficult to meet the requirements of the increasingly restrictive legislation and to deal with this problem in a sustainable way.

A treatment process suitable to treat or even valorize and recycle this wastewater must be found. Biological treatment is the most common process used to treat organics-containing wastewaters [5]. These processes are frequently used since they are more economic and environmentally friendly, using optimized natural pathways to actually destroy pollution, not only transform it into another form [6]. Artiga et al. [7] used a hybrid membrane bioreactor for the treatment of water generated during tuna cooking with brine, from a fish canning industry, with 7.8–11.7 g COD/L, 1.2–1.8 g N/L and up to 84 g/L of salt. After 73 operating days they achieved a COD removal efficiency of 92%. The effect of a lipase-rich enzyme preparation was evaluated in an up-flow anaerobic sludge blanket bioreactor (UASB) by Alexandre et al. [8] to treat fish-processing plant wastewater containing 1500 mg oil and grease (O&G)/L. They concluded that the enzymatic pre-hydrolysis step together with anaerobic treatment improved the quality of the treated effluent and reduced operational problems. Riano et al. [1] studied the treatment of fish processing wastewater with microalgae-containing microbiota at 23 and 31 °C, achieving approximately 70% of COD and phosphate removal regardless of temperature. However, further research is needed in order to optimize operational conditions considering the energy-efficiency of the system. Although biological treatment of carbonaceous, nitrogenous and phosphorous pollution has proved to be feasible at high salt concentrations [9], the performance achieved depends on proper reactor conditions and characteristics of the effluent.

Single-variable optimization methods are not only tedious but also can lead to misinterpretation of results, especially because the interaction between different factors is overlooked [10]. Therefore, at present, the multivariate optimization methods have been chosen for numerous research works. A factorial design of experiments has been extensively used to process development and optimization because it allows the simultaneous analysis of the effects of many process variables at different levels as well as their interactions. The experimental design and response surface methodology (RSM) are useful statistical techniques to identify and optimize factors that influence a particular process, with a reduced number of experiments to be performed. This multivariate technique fits the experimental data to a theoretical model through a response function, estimating this way the model coefficients [11,12]. RSM and factorial design have been extensively applied in many areas of wastewater treatment such as optimization of the treatment conditions of an oily wastewater by a nano-porous membrane process [13], optimization of an electrocoagulation process for the treatment of wastewater from biodiesel production [14], optimization of a textile dye wastewater degradation by enzymatic catalysis [15,16], minimization of organic content of simulated industrial wastewater by Fenton type processes [17], etc. To our knowledge, there are no reports in the literature on the optimization of fish canning wastewater treatment by activated sludge.

Then, the major goal of the experimental work being reported here was to create a methodology for optimization and control of a process that is still poorly controlled and that could be applied in similar factories. Thus, the aim was to characterize the effluent of one unit of canned fish production, over time, regardless of the type of fish, in order to assess the effluent seasonal variability. Based on this characterization, the conditions of treatment by activated sludge were optimized. Response surface methodology and a polynomial function were applied to set the optimum operating conditions for maximum reduction of dissolved organic carbon (DOC).