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Research article

Case studies on the physical-chemical parameters' variation during three different purification approaches destined to treat wastewaters from food industry

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ABSTRACT

The paper presents a set of three interconnected case studies on the depuration of food processing wastewaters by using aeration & ozonation and two types of hollow-fiber membrane bioreactor (MBR) approaches. A secondary and more extensive objective derived from the first one is to draw a clearer, broader frame on the variation of physical-chemical parameters during the purification of wastewaters from food industry through different operating modes with the aim of improving the management of water purification process. Chemical oxygen demand (COD), pH, mixed liquor suspended solids (MLSS), total nitrogen, specific nitrogen (NH_4^+, NO_2^-, NO_3^-) total phosphorous, and total surfactants were the measured parameters, and their influence was discussed in order to establish the best operating mode to achieve the purification performances. The integrated air-ozone aeration process applied in the second operating mode lead to a COD decrease by up to 90%, compared to only 75% obtained in a conventional biological activated sludge process. The combined purification process of MBR and ozonation produced an additional COD decrease of 10–15%, and made the Total Surfactants values to comply to the specific legislation.

1. Introduction

Wastewater purification is a complex, applied science which aims to find the best solutions to generate reusable and safely dischargeable effluents, whatever the type of residual water is. The main problem regarding the management of wastewaters is of qualitative nature, since good quality water necessary for agriculture and industry, the two main consumers, is no longer carefree available. This is the reason why studies in this domain are more than necessary, and better and better solutions are needed to be discovered. Recent studies are concerned in finding depuration solutions for wastewaters from food industry (Kong et al., 2016; Nunes et al., 2016; Ghimpusan et al., 2015; Gugała et al., 2015; Julien and Safferman, 2015), livestock (García-Gonzalez et al., 2015), and urban areas (Ji et al., 2015).

Food industry uses large amounts of water in many purposes, for example as sterile water to produce food, but also in cleaning purposes, for transportation, or refrigeration (Blocher et al., 2002; Chen et al., 2000; García-Ballesteros et al., 2016). As a consequence of diverse consumption, the quantity and the composition of wastewater from food industry ranges significantly (Banaeian et al., 2016; Hanafie and Alfiana, 2016). The effluent's characteristics consist in large quantities of total suspended solids (TSS), several chemical forms of nitrogen, fats, proteins, oils and other kinds of organic matter, phosphorus, chlorine and other chemicals used in cleaning and sanitizing purposes (Meneses and Flores, 2016; Gugała et al., 2015; Ji et al., 2015; Durán et al., 2013; Bressan et al., 2004).

Wastewater from food-processing facilities has some particularities compared with municipal wastewater, meaning it is organic, rich in nutrients, biodegradable, nontoxic and can be treated by conventional biological technologies (Kotsanopoulos and Arvanitoyannis, 2015; Lee et al., 2002). Particularly, food canning industries generate a large variety of difficult wastewaters,

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which require a more complex treatment (Anjum et al., 2016; Parra-López et al., 2016). A complex treatment process will start, for example, with removing the oils and fats by flotation in conventional plants. But the seeds, tomato skins, or colloidal fractions hinder the purification process (Álvarez et al., 2011; Anjum et al., 2016). All these aspects, at which can be added the plant localization and the water quality impact assessment represent defining characteristics for selecting a wastewater treatment method (Julien and Safferman, 2015; Blocher et al., 2003; Lazaridis et al., 2004).

Generally, the parameters Biochemical Oxygen Demand (BOD_5) and COD for wastewater from the food industry are 10 or even 100 times higher than municipal wastewater. Odors are also a typical problem. Unpleasant odors are usually the result of gases (hydrogen sulphide) produced by the anaerobic decomposition of organic matter (Kong et al., 2016).

In the present research work, the treatability of food processing wastewater from process of cooking of tuna, basil tomato, and olives, wastewater with a COD of 3500–10000 mg/L was evaluated in a combined system composed of well-arranged sequences: screening, dissolved air flotation (DAF), two serial steps of aerobic biological treatment, advanced oxidation process (AOP), membrane bioreactors (MBR) ultrafiltration, and ozonation. The chemical parameters of this kind of wastewater, meaning BOD_5, COD, total suspended solids (TSS), pathogenic microorganisms, pH, inorganics (P and N), may vary a lot, which complicates the purification process.

2. Materials and methods

2.1. Description of the WWTP

The waste water treatment plant (WWTP) where the present experiments were conducted is placed in the north-west of Italy, close to the shores of Ligurian Sea, in Chiusanico village, Imperia province, Liguria region. The WWTP, with the capacity to treat 100 m^3/d wastewaters from food processing, was designed, constructed and installed by GOST Ltd and belongs to the Company of Liguri Food Specialties Spa ("Compagnia delle Specialità Alimentari Liguri Spa"). The main modules that compose the installation are presented in Fig. 1.

The WWTP is designed to treat residual waters from the obtaining of tuna cans and vegetable food products like tomato, asparagus, red onion, mushrooms, olives, spices etc., the resulted waste waters having the aspect from the graphical abstract. Wastewater resulting from the manufacturing process contains significant amounts of suspended solids (mixed liquor suspended solids – MLSS), fats and oils, suspended and dissolved organics (COD, BOD_5), with occasional high salinity (sodium chloride). More than twenty different products are manufactured at the same facility, which means that the resulted wastewater varies on hourly, daily, and seasonal basis. These factors, plus the use of cleaning products like detergents, bleach, peracetic acid, are heavily influencing the downstream wastewater composition (Meneses and Flores, 2016). The pH can vary between 3.5 and 5.5, TSS between 2000 mg/L and 5000 mg/L, FOGs (fats, oil and grease) between 10 and 2000 mg/L, COD between 3000 and 10000 mg/L, BOD_5 between 1400 and 2000 mg/L, TKN between 38.5 and 93.5 mg/L, TP between 23.3 and 50.6 mg/L, salinity > 1200 mg/L.

The primary treatment processes for this kind of wastewater are: (1) screening with a bar screen brush able to retain all the solid materials with a size bigger than 0.75 mm (TSS removal 80–90%), (2) flotation – wastewater flows naturally in the flotation tank (removal of 80% suspended solids, 90% oils and fats, 30% BOD_5), (3) flow equalization in a settling tank and pH adjustment (Ghimpusan et al., 2015).

The secondary treatment step of wastewater is completed in two biological tanks, (4) and (5); after the second tank the removal of COD is 80–90%. Primary and secondary biological treatment methods aimed to remove the suspended solids, BOD_5 and nutrients to some extent. However, to guarantee a safe discharge of the treated effluent, tertiary and disinfection treatments are also necessary. In this sense, firstly was applied an advanced physical-chemical oxidation process (AOP), and after that the sludge was treated by filterpress. The plant was operated with this system for 3 years, but the effluent was not appropriate for discharge into the waterbody or reuse.

This was the starting point of the present study, which has set to observe the parameters' variation upon to addition of other three different purification processes, named 1, 2, and 3. The first additional treatment process that will be described and analyzed was implemented on 01.02.08 and consisted in the introduction of three membrane bioreactors inside the biological tanks. The second additional treatment was the ozonation step, which was

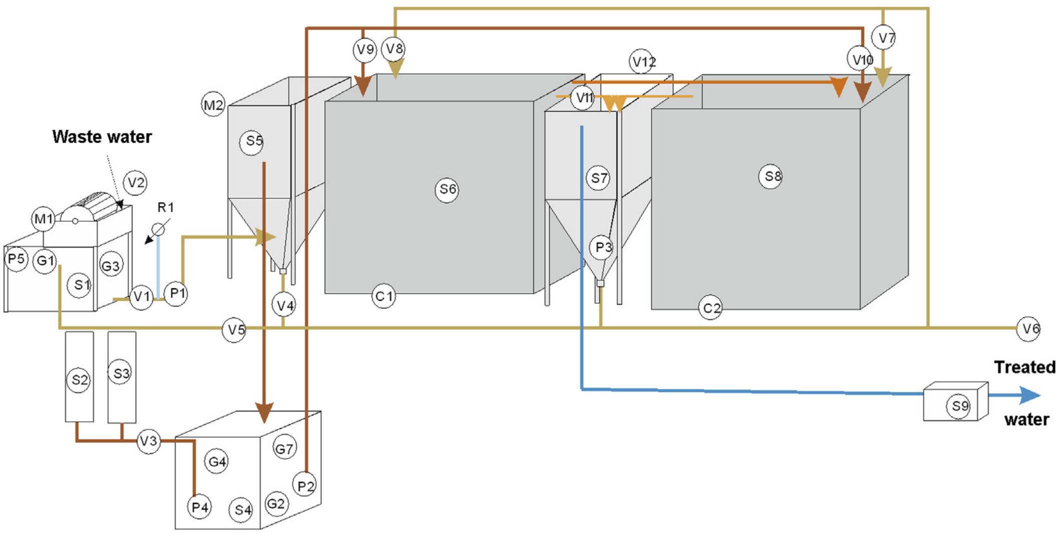

Fig. 1. Scheme of the WWTP used in this study: S1 – container for screened wastewater; S2, S3, and S4 – tanks for floated wastewater; S5 – dissolved air flotation tank; S6 and S8 – aeration tanks; S7 – settling tank; S9 – chlorination tank; G1–G7 – level sensors; V1–V12 – pneumatic valves, P1–P7 – pumps; M1, M2 – motors; R1 – air flow regulator.