Assessing the influence of oil and grease and salt content on fish canning wastewater biodegradation through respirometric tests

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A B S T R A C T
Fish canning industry wastewaters have high organic matter, oil and grease and salt (NaCl) content, which make difficult a proper treatment before discharge. In this work, their treatment was evaluated via activated sludge aerobic biological process through respirometric tests. Inhibition was found to be significant for NaCl concentrations higher than 17.5 g/L. On the other hand, the oil and grease content affects the wastewater biodegradability in the same way that the organic matter content expressed as chemical oxygen demand: the lower oil and grease and organic matter concentrations, the lower the percentage of wastewater biodegradability. As a final conclusion, the aerobic biological treatment process by activated sludge proved to be appropriate to treat fish canning industrial wastewaters, leading to high organic matter degradation rates (average value of 4900 mgO₂/gCOD.d). Additionally, the experimental results achieved with the respirometric tests may be useful for the design of activated sludge plants to treat this type of wastewaters.

1. Introduction

Recently, there has been an increase in the number of fish canning industries across the world. The wastewaters produced in this type of industries vary widely, depending on the production period, on the type of fish and/or on the process used. Their treatment is complex due to their saline nature (they present high NaCl concentration) and due to the presence of oils and other organic compounds (Cristóvão et al., 2015).

Conventional biological treatment processes, in particular activated sludge systems, are widely used in wastewater treatment plants (WWTPs). However, toxic and inhibitory compounds such as volatile organic compounds (VOCs), salts, heavy metals, oils and greases, aromatic or chlorinated organics are usually found in industrial wastewaters and their negative impact on microorganisms’ activity requires specific attention (Ricco et al., 2004). Toxicant effects are quite complex, not easily predictable, and could include biological sludge inhibition, decreasing the organic waste biodegradation and leading to the modification of the sludge settleability properties, which often decreases the solid—liquid separation efficiency.

Wastewaters with high salt content are known to be significantly more difficult to treat by conventional biological methods, leading to cells plasmolysis or activity loss (Kargi and Uygur, 1996). Some studies were performed in order to assess the effects of synthetic wastewaters with high salt content on biomass activity (Kokabian et al., 2013; Zhan et al., 2000). Panswad and Anan (1999) showed a reduction on the organic content (in terms of chemical oxygen demand (COD)) removal efficiency from 97 to 60% as the NaCl content increased from 0 to 30 g/L when treating a synthetic wastewater by an anaerobic/anoxic/aerobic process. Dincer and Kargi (2001) also reported a decrease of COD removal efficiency when increasing the salt concentration on the biological treatment of a synthetic saline wastewater using a rotating biodisc unit.

Oil and grease (O&G) are known to be part of wastewater organic composition. However, due to their floating nature, they need to be firstly removed, if no they will affect the oxygen transfer to the wastewater in the aerobic biological treatment. Despite suspended O&G can be easily removed by physical methods,
emulsified ones contribute also to biochemical oxygen demand (BOD) and COD and must be treated in an appropriate manner. Once the costs of physicochemical treatments are particularly high, biological treatment processes are also commonly used for this purpose. However, O&G exact degradation behavior in these treatment processes is not well understood. In biological wastewater treatment systems, O&G are generally believed to be biodegradable, however they contribute to a lower microbial activity (Sunny and Mathai, 2013) mostly due to accumulation onto water treatment systems, O&T treatment processes is not well understood. In biological waste- biological treatment processes are also commonly used for this Once the costs of physicochemical treatments are particularly high, 

2.1. Wastewater sample collection and characterization

The wastewater samples were collected in a selected fish canning industry were collected and characterized. After that, the corresponding biodegradability and toxicity were assessed through different types of respirometric tests with activated sludge, using a BM-T Advance sludge respirometer (SURCIS L., Spain).

2.2. Biological sludge source

The aerobic activated sludge was obtained from Freixo Municipal Wastewater Treatment Plant (Portugal) and was allowed to air for 24 h before being used in the tests, in order to remove the residual COD in the liquid phase. The activated sludge was analyzed for volatile suspended solids (VSS) through the standard procedure reported in Standard Methods (APHA, 2012).
other hand, static respirometry is simpler, allowing for a direct determination of the respiration rate under actual conditions but is limited to a relatively short dissolved oxygen concentration range before oxygen may become limiting. This way, it is important to evaluate both methods to decide which is the best to apply in the case under study.

For OUR biodegradability measurements, the respirometer was loaded with 700 mL of activated sludge from the Freixo municipal wastewater treatment plant (Portugal). In order to inhibit the nitrification process and only measure the oxygen consumption by the heterotrophic bacteria, 3 mg of N-allythiourea per gram of volatile suspended solids (VSS) was added to the activated sludge. The experiments were performed at 20 °C and pH of 6.5–7.5. 30 mL of each sample were added to the respirometer vessel, the aeration and agitation were stopped and the oxygen consumption was monitored automatically during the assay, until dissolved oxygen values lower than 1 were reached. These tests were carried out using sodium acetate as a reference substrate to compare with the sample under study. The biodegradability of the sample was determined by Eq. (1):

\[
\text{OUR Biodegradability (\%) = } \frac{\text{OUR}_{\text{sample}}}{\text{OUR}_{\text{reference}}} \times 100
\]

where \(\text{OUR}_{\text{reference}}\) is the oxygen uptake rate of the reference sample (sodium acetate) (mgO₂/L h) and \(\text{OUR}_{\text{sample}}\) is the oxygen uptake rate of the sample (mgO₂/L h).

For biodegradability measurements through R tests, the respirometer was also loaded with 700 mL of activated sludge from the same WWTP. The 3 mg of N-allythiourea per gram of volatile solids were also added in order to inhibit the nitrification process. The experiments were performed at 20 °C and pH of 6.5–7.5 under continuous aeration and agitation. 30 mL of each sample was added to the respirometer vessel and the oxygen consumption was monitored automatically during the assay. At the end of the test, the respirometer software gives the biodegradable fraction of the sample (bCOD) based on the total oxygen consumption measured and the normal biomass yield (0.67 gCODbiomass/gCODdegraded, as mentioned in the respirometer manual) for activated sludge from conventional municipal wastewater treatment plants. The sample biodegradability based on R tests is calculated through Eq. (2):

\[
R_{\text{Biodegradability (\%) = }} \frac{\text{bCOD}}{\text{COD}}
\]

The toxicity of the wastewater samples was evaluated through OUR tests by comparing the oxygen uptake rate from an assay performed with the sludge and 30 mL of a biodegradable reference substrate and the oxygen uptake rate from another assay with sludge previously being the contact with 30 mL of the wastewater sample and 30 mL of the same reference sample. The reference substrate used was sodium acetate in an amount corresponding to the dissolved organic carbon (DOC) of each sample under study. Thus, the toxicity percentage was evaluated as follows:

\[
\text{OUR Toxicity (\%) = } \frac{\text{OUR}_{\text{reference}} - \text{OUR}_{\text{sample-reference}}}{\text{OUR}_{\text{reference}}} \times 100
\]

where \(\text{OUR}_{\text{sample-reference}}\) is the oxygen uptake rate of the reference sample (sodium acetate) achieved with a sludge that already contacted with the wastewater sample and \(\text{OUR}_{\text{reference}}\) is the oxygen uptake rate of the reference sample.

The toxicity of the wastewater samples was also evaluated through R tests by comparing the bacterial activity in two assays: one containing the sludge and 30 mL of a biodegradable reference substrate and another containing the sludge and 30 mL of the target sample. In all cases, the tests were extended until the biomass reached the maximum respiration rate (\(R_{\text{max}}\) mgO₂/L h) and the toxicity percentage of each sample can be expressed quantitatively according to the following equation:

\[
R_{\text{Toxicity (\%) = }} \left(1 - \frac{R_{\text{max sample}}}{R_{\text{max reference}}}\right) \times 100
\]

where \(R_{\text{max sample}}\) is the maximum dynamic respiration rate relative to the sample assay and \(R_{\text{max reference}}\) is the maximum dynamic respiration rate relative to the reference assay (sodium acetate). To evaluate the effect of NaCl and O₂G content on the wastewater organic matter biodegradation, two of the samples under study were chosen: one with low NaCl and O₂G concentrations (03/31/2014 C), to be possible to add different NaCl amounts and see the isolated effect of the NaCl concentration variation and another one with a high O₂G amount and a low NaCl concentration (04/14/2014 C) in order to be able to remove O₂G from the wastewater and to study lower O₂G concentrations. This way, different NaCl quantities were added to the 03/31/2014 C wastewater sample (containing originally 4 g/L of NaCl and 1.9 g/L of O₂G) in order to obtain wastewater samples with 8, 17.5 and 30 g/L of NaCl (dosages within the range found in wastewater characterization) to study the salinity effects on the wastewater biodegradability and toxicity through R tests. Similarly, different quantities of floatable O₂G were removed from the 04/14/2014 C wastewater sample containing originally 11.1 g/L of O₂G, achieving wastewater samples with 7.5 and 3.6 g/L of O₂G, also to assess O₂G effects on the results from R tests.

Biodegradability percentage data were utilized to build the biodegradability percentage curve as a function of the contaminant (NaCl and O₂G) concentration tested.

Finally, the reaction kinetics was investigated by fitting the experimental data of samples degradation to a pseudo–first order kinetic equation: \(ln \left(\frac{C}{C_0}\right) = -k \cdot t\), where \(C\) represents the biodegradable organic matter concentration (mg/L) at time \(t\) (h), \(C_0\) is the initial biodegradable organic matter concentration (mg/L) and \(k\) is the reaction kinetic constant (h⁻¹).

Each activated sludge sample was used only for one test: in other words, the different NaCl or O₂G concentrations were tested with renewed sludge samples, to avoid partial acclimatization of the biomass to the contaminant and consequent possible underestimation of the toxicity effects. In order to ensure the reproducibility of the measurements, all tests referring to the same contaminant were done with the same stock of activated sludge. Different stocks of municipal sludge were used during the whole experimental period in order to avoid using the sludge stored for too long periods of time.

3. Results and discussion

In the subsections below we describe and discuss the results from the characterization of the fish canning wastewater samples, as well as the ones obtained from the respirometric tests.

3.1. Characterization of fish canning wastewater

Wastewater characterization is a critical factor in establishing an effective management strategy or treatment process. The fish canning wastewater characteristics vary according to the production process in a specific fish canning industry. In order to obtain a representative set of information on effluent properties, several
samples were collected at different times and analyzed. The data from the analysis of 23 parameters in 11 wastewater samples are presented in Table 1. It has to be noted that data below a detection threshold was replaced by the equipment detection limit. As expected, the results obtained show that the characteristics of the fish canning industrial wastewater under study present high variability, despite the fact that all samples were taken from a common wastewater reception well. The different wastewater streams come mainly from the following processes: brine water from fish cleaning; melted ice contaminated with blood and defrost water; water containing blood, guts and fish waste, generated in the eviscerating stage; blood, grease and liquid waste from the cooking step; oils and fish remains from sauces filling stage; water from cans, equipment and facilities washing steps. Thus, the volume and characteristics of the final effluent change significantly throughout the day, depending on the streams that are being released. According to information from the fish canning company, several fish types can be processed every day, namely, sardines, mackerel and tuna. This way, it is hard to know what is the contribution of each species to the final effluent characteristics.

In the case of composite samples it would be expected that the parameters do not differ greatly from sample to sample, being, this way, more representative of the effluent composition. However, this was not observed, confirming again the high variability of fish canning industry wastewaters not only during the day but from day to day.

Table 2 presents the mean, the respective standard deviation, the minimum and the maximum values obtained from the characterisation of all samples. Again, the high BOD₅ and COD values show effluent’s strong contamination with organic matter. As was aforementioned, the wastewater presents also high values of TSS, SS, COD and salt content (analyzed in terms of Cl⁻ and Na⁺ concentrations and conductivity values). Typically the pH of fish processing industry wastewaters varies between 5.7 and 7.4, being on average equal to 6.4 (Technical Report Series FREMP, 1994). In this case, the pH varied between 5.6 and 9.6, with an average value of 6.8, close to the value reported in the literature (Technical Report Series FREMP, 1994). This pH average value indicates that the wastewater is favorable for biological treatment. Suspended solids are one of the contaminants potentially causing more impact on the environment. TSS concentration in this type of effluents is generally high, between 2000 and 5000 mg/L (Novatec, 1994; Prasertan et al., 1994), which also happened in this study, where the TSS mean value was 2988 mg/L. The COD and BOD₅ values varied between 3314 and 17,048 mg/L and 2420–13,626 mg/L. The ranges found confirm, once again, the high variability of this type of wastewaters. According to the literature, the organic matter content in fish canning industry wastewaters is in the range of 10,000–50,000 mg/L (Chowdhury et al., 2010). Fish processing wastewater COD:BOD₅ ratios varies widely within and among processing plants ranging from 1.1:1 to 3:1 (Technical Report Series FREMP, 1994), which was also verified in this study, where an average ratio of 1.7:1 was found. This ratio indicates that the organic matter in the wastewater is biodegradable. The O&G content shows an average value of 3933 mg/L, value between the values reported in literature (20–4000 mg/L) (Chowdhury et al., 2010). The average concentration of NaCl in the effluent is about 10,800 mg/L. Although typical values of NaCl

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### Table 1

<table>
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<th>Parameter</th>
<th>02/11/2014</th>
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<th>02/18/2014</th>
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<th>04/14/2014</th>
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<tr>
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<tr>
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<tr>
<td>NaCl (mg/L)</td>
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<table>
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<th>W</th>
<th>PM</th>
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<tr>
<td>pH</td>
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<td>7.5 ± 0.4</td>
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</tr>
<tr>
<td>TSS (mg/L)</td>
<td>154 ± 21</td>
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<td>154 ± 21</td>
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<tr>
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concentration in similar effluents were not referenced in the literature, this parameter is very important, since high salt content can inhibit the biological processes.

Table 3 presents some ratios between parameters, which are important for anticipating the results of aerobic treatment tests. The ratio BOD₅/COD is commonly used to evaluate the wastewater biodegradability. According to Ballesteros Martín et al. (2010), biodegradability values of 30% or higher correspond to samples classified as very biodegradable and can effectively be treated by a biological process, a value between 10 and 30% means that the sample is biodegradable, whereas values lower than 5% indicate that the sample is not biodegradable (values between 5% and 10% indicate samples with low biodegradability). As shown in Table 3, all samples proved to be very biodegradable, as expected, since all BOD₅/COD ratio values are above 30%, with the exception of 03/18/2014 PM sample, which exhibits a biodegradability of 26 ± 3%.

The BOD₅:N:P ratio is of utmost importance to predict the success of biodegradation under aerobic conditions. For an effective aerobic treatment, as a general rule, the wastewater nutrients weight ratio must be BOD₅:N:P = 100:5:1, which means that, for each 100 g of BOD₅ present in the effluent, 5 g of N and 1 g of P are needed (Metcalf and Eddy, 1995). The lack of N and P gives rise to scattered flakes formation and to the growth of filamentous bacteria, which affect the wastewater treatment efficiency. According to the results present in Table 3, the 04/15/2014 C sample is the only one that does not have the required amount of N and P, which could impair the performance of the aerobic biological treatment. This way, in general, the results indicate that almost all samples meet the minimum nutrient ratios necessary for an effective biological treatment.

The Cl/Na ratio was also determined in order to check if Cl⁻ and Na⁺ ions are only derived from sodium chloride salt (NaCl) or if they derive from other salts. Taking into account the values presented in Table 3, one can conclude that in most samples the ions sodium and chloride are derived only from NaCl salt, since their molar ratio is approximately 1:1. However, the ratio is lower than 1 in some samples, which means that the sodium ions may come from other salts, such as sodium nitrate (NaNO₃), sodium nitrite (NaNO₂), sodium bromide (NaBr), and sodium sulfate (Na₂SO₄).

3.2. Respirometry assays

Respirometry is a technique widely used to evaluate aerobic biodegradation of certain substrates. Thus, respirometric tests with activated sludge were applied to wastewater samples from the selected fish canning industry at northern Portugal. Firstly, the sample biodegradability (Eq. (1)) and toxicity (Eq. (3)) were evaluated through OUR tests. It has to be noted that, throughout the respirometric tests, biomass oxygen consumption was continuously recorded. In these tests, the oxygen supply is stopped and the OUR values are obtained only for the initial degradation phase of the reference substance, sodium acetate, and of each of the samples under study. By observing the results present in Table 4, it is possible to verify that according to OUR tests, all samples are 100% biodegradable. However, it must be noted that, in the OUR tests, since the oxygen supply is stopped, it is not guaranteed that the samples were totally degraded and the biodegradability values may have a certain calculation error.

To find any chronic toxicity through OUR tests, sodium acetate was added after biomass exposure to wastewater samples, to evaluate again the biomass response. Fig. 1 shows the OUR curves obtained in the OUR tests performed to determine the toxicity of 03/31/2014 C sample, as typical oxygen concentration profiles observed in the respirometric tests for all wastewater samples under study. It has to be noted that the OUR values of the sodium acetate solution varied along the experimental study due to the activity variation of the different stocks of the biological sludge. In the specific case of 03/31/2014 C sample, comparing the sodium acetate curve and the response of the same substrate after exposure of the biomass to wastewater sample, an OUR decrease of about 27.5% was detected (OUR_Toxicity % in Table 4). This result means an inhibitory effect on the biomass activity. OUR decrease was well detected just after the sample addition, no lag phase was observed. This is a good point for process control: early detection of toxicants allows the prompt intervention of opportune control strategies to reduce the biomass-toxicant contact time (Ricco et al., 2004).

The results presented in Table 4 show that, with the exception of two samples, 03/18/2014 AM and 03/31/2014 C, that exhibited some toxicity (2.3% and 27.5%, respectively), the biomass respirometric activity was normal, completely consuming the biodegradable substrate (according to the dissolved oxygen recorded). This means that continued exposure of the biomass to fish canning wastewater, in general, does not affect its activity.

In order to confirm the results from OUR tests, the biodegradability and toxicity of all samples were also assessed through R tests (Eq. (2) and (4), respectively). The values obtained correspond to the entire degradation of the sample, giving more reliable results than those obtained in OUR tests. This can be observed in Fig. 2,
where the $Rs$ profile of the 05/06/2014 C sample degradation is represented as a typical profile obtained in the R tests of the fish canning wastewater samples. As expected, the respiration rate, $Rs$, increases from the beginning of the sample degradation up to a maximum, starting then to decrease to zero, corresponding to the total sample degradation. Table 4 presents also the results achieved with R tests and it is possible to see that this type of effluent, in general, has a high percentage of biodegradable organic compounds and has no toxicity, meaning that, much probably, it is possible its treatment through microbiological processes. The $Rs$ parameter is related to the exogenous breathing rate and is directly correlated with bCOD. Typically, the higher the degraded matter amount, the higher the $Rs$ value. This trend was found in most samples, however, some exceptions were observed. This was the case of 02/11/2014 PM and 04/15/2014 C samples that, despite having higher COD values, showed low $Rs$ values (36.3 and 36.6 mgO$_2$/L h, respectively). Looking at the parameters values achieved in their characterization (Table 1) it is possible to observe a lower ratio of O$_2$G and NaCl concentrations in relation to the COD value (0.31 and 0.26, respectively, for 02/11/2014 PM and 0.19 and 0.15, respectively, for 04/15/2014 C) when compared to the samples with the highest $Rs$ values. In the case of 05/06/2014 C sample, despite having a lower COD amount, it reached a very...
high Rs value (68.8 mgO₂/L h), since the O₆G/COD and NaCl/COD ratios are higher (0.75 and 2.09, respectively). So, it can be concluded that the higher the ratios O₆G/COD and NaCl/COD, the higher the value of Rs. This can be confirmed by later experiments for the evaluation of O₆G and NaCl concentrations influence. The CO value indicates the consumed oxygen in the sample organics oxidation, being directly proportional to the degraded COD amount.

The U parameter corresponds to the bCOD degradation rate (mgₚbCOD/L h) and the q parameter (Eq. (6)) corresponds to the specific bCOD degradation rate (mgₚbCOD/mgVSS,d) and are determined by Eqs. (5) and (6), respectively:

\[ U = \frac{S_b}{T} \times \frac{S_o}{K_o + S_o} \]  
\[ q = \frac{24 \times U}{VSS} \]  

Where \( S_b = bCOD \times D, D = V_f / (V_f + V_m) \times (V_m/1000), V_f \) is the sample volume utilized in the test (mL), \( V_f \) is the sludge volume utilized in the test (mL), \( T \) is the complete test time (h), \( S_o \) is the dissolved oxygen average along the aerobic activated sludge process (mgO₂/L) and \( K_o \) is equal to 0.2.

These two parameters are related to each other through VSS value, varying in the same proportion, but with a constraint: the activated sludge used in each sample test was not always the same. The U parameter is also related to Rs and varies according to the ratios O₆G/COD and NaCl/COD too. In general, the samples in which the ratio O₆G/COD is higher than the ratio NaCl/COD, show higher organic matter degradation rates, since a larger part of O₆G contributes to the wastewater organic matter (Sunny and Mathai, 2013) and the NaCl is known to be an inhibiting factor of biological treatment processes (Pernetti and Di Palma, 2005). Chipasa and Medrzycka (2008) carried out studies to characterize the transformation of lipids in activated sludge under aerobic conditions. However they found that the overall residual lipid content could not be reduced to values below 300 mg/L from an initial content of 2000 mg/L, showing that the use of microbial activity for lipids complete removal is limited, being necessary the development of new treatment methods.

The kinetic parameter \( k \) was determined by fitting the experimental data of samples degradation to a pseudo-first order kinetic equation. From the values obtained (Table 4), it is possible to see that the lower k value corresponds to the sample 04/15/2014 C, the same sample that does not meet the minimum nutrients ratio (BOD₃:N:P) required. This kinetic constant varies also with O₆G and NaCl proportions regarding the COD value. So, it can be normalized by the initial Dissolved Organic Carbon (DOC) value, thus considering only the soluble organic substances, since the samples are filtered to DOC determination, trying to remove, at the same time, the particulate matter influence on COD and O₆G values. Analyzing the values of the normalized kinetic constant presented in Table 4, it is possible to conclude that the lowest value is still that of the sample referred above. This finding was expected since O₆G in the wastewater is essentially emulsified and the COD is almost totally soluble. According to Ramalho (1977), the kinetic constant for domestic sewage biodegradation varies between 0.017 and 0.03 mgₚSS/l d⁻¹. It is possible to compare the kinetic constant obtained in this work with those reported in the literature, the k average value was divided by the VSS concentration used in the respirometric assay, that varied in the range of 2500–3000 mg/l. Considering the average value of 2750 mg/l it was achieved a k average value for the wastewater samples under study of 0.01 mgₚSS/l d⁻¹, value below of the one verified to the domestic sewage degradation, probably due to the inhibition factors mentioned above.

From Table 4 it can be concluded that the O₆G and NaCl concentrations influence the organic matter degradation of fish canning wastewaters through aerobic suspended-growth processes. In order to verify these influences, two wastewater samples were selected: one with a low NaCl concentration and an amount of O₆G not too high, in order to be possible to add different NaCl amounts to obtain different concentrations, keeping the same values for the remaining parameters; and another sample with a large O₆G amount and a low NaCl concentration in order to be able to remove some O₆G and obtain also different O₆G concentrations in the wastewater. Thus, these samples were modified aiming at varying only one parameter at each time, in order to be able to study the influence of both parameters individually on the organic matter degradation by an aerobic activated sludge process.

The sample selected to study the NaCl dosage variation was the 03/31/2014 C. This sample has a low NaCl concentration, in the order of 4035 mg/L, and also a low content of O₆G, about 1962 mg/L. Different quantities of NaCl were then added to the wastewater sample in order to attain 8000, 17,500 and 30,000 mg/L NaCl. These values were set according to the NaCl average value (10,782 mg/L) found in the wastewater characterization (Table 1) and the most likely variation range of their concentrations. Table 5 shows the results obtained in the R tests carried out for these samples with different NaCl concentrations. One of the values that stands out is the toxicity verified in the sample with NaCl concentration of 30,000 mg/L (3.2%), which had not been previously observed in any sample, even in the sample 03/18/2014 AM, which has a NaCl concentration of about 36,000 mg/L. However, since these wastewaters have a composition high variable and that there is a large influence of the different parameters on their biological degradation, either individually, or by their interaction, one must pay attention on the toxicity of this type of wastewaters when they have NaCl concentrations higher than 17,500 mg/L.

Thus, looking at all values obtained from the R tests and at the kinetic constant obtained by fitting a pseudo-first order kinetic model to the experimental data, one can conclude that the values of Rs, U, q and k decrease when increasing the NaCl concentration. The difference between the results obtained for the lowest NaCl concentrations and the NaCl concentration of 17,500 mg/L is not very large (about 5%), but when the NaCl concentration is increased to 30,000 mg/L, the difference becomes significant (about 25%).
Aerobic respirometric results obtained with the 03/31/2014 C fish canning industry wastewater sample with different NaCl dosages.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>03/31/2014 C</th>
<th>8 g/L NaCl</th>
<th>17.5 g/L NaCl</th>
<th>30 g/L NaCl</th>
</tr>
</thead>
<tbody>
<tr>
<td>COD (mgO₂/L)</td>
<td>4759</td>
<td>4759</td>
<td>4759</td>
<td>4759</td>
</tr>
<tr>
<td>O₂G (mg/L)</td>
<td>1962</td>
<td>1962</td>
<td>1962</td>
<td>1962</td>
</tr>
<tr>
<td>NaCl (mg/L)</td>
<td>4035</td>
<td>8169</td>
<td>17,484</td>
<td>27,934</td>
</tr>
<tr>
<td>R_Biodegradability (%)</td>
<td>50.9</td>
<td>49.6</td>
<td>47.5</td>
<td>38.2</td>
</tr>
<tr>
<td>R_Toxicity (%)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>3.2</td>
</tr>
<tr>
<td>Rs (mgO₂/L h)</td>
<td>38.7</td>
<td>33.7</td>
<td>22.7</td>
<td>13.7</td>
</tr>
<tr>
<td>CO (mgO₂/L h)</td>
<td>799</td>
<td>782</td>
<td>745</td>
<td>601</td>
</tr>
<tr>
<td>bCOD (mgO₂/L h)</td>
<td>2420</td>
<td>2370</td>
<td>2259</td>
<td>1820</td>
</tr>
<tr>
<td>U (mgO₂/L h)</td>
<td>2132</td>
<td>1996</td>
<td>1475</td>
<td>816</td>
</tr>
<tr>
<td>q (mgO₂/mgVSS d)</td>
<td>20.4</td>
<td>17.6</td>
<td>11.4</td>
<td>6.3</td>
</tr>
<tr>
<td>k (h⁻¹)</td>
<td>1.702</td>
<td>0.822</td>
<td>0.498</td>
<td>0.317</td>
</tr>
</tbody>
</table>

Table 6 shows the O&G and COD concentrations for each new sample analyzed and the respective percentages of biodegradability and toxicity, being possible to verify that the percentage of biodegradability decreases from the original sample to the other, more than the respective COD/O&G ratio. Table 6 shows also the results obtained in the R tests and the kinetic constants achieved from the adjustment of the pseudo-first order kinetic model to the experimental data. It is possible to see that as the O&G dosage decreases, the respiration rate (Rs) also decreases, as well as the bCOD degradation rate (U). This reduction may also be due to the decrease in the sample pollutant load, making difficult to say with certainty that the lower the O&G dosage, the lower the percentage of the wastewater biodegradability. Regarding the kinetic constant determined by fitting a pseudo-first kinetic model to the experimental data, it was found that, in this case, it increases with the reduction of O&G dosage, probably due to the formation of O&G floating aggregates in the case of high O&G dosage, that may cause some inhibition in the microorganisms’ activity. However, it has to be noted that, depending on the O&G type present in industrial wastewaters, microorganisms could respond differently during the degradation process. Primasari et al. (2011) studied the feasibility of an aerobic biological process to treat oily wastewater from palm oil food industry and found that higher sludge concentrations led to higher O&G removal while moderate sludge concentration led to better results in COD removal. In fact, oil and greases are known to be, generally, biodegradable and, thus, regarded as part of the organic load which is treated (Sunny and Mathai, 2013). Other authors also studied the treatment of highly oily wastewaters and reached similar conclusions. On the other hand, Chipasa and Medrzycka (2008) also verified the high ability of lipids to form floating aggregates, thereby hindering the wastewater biological treatment.

4. Conclusions

A respirometric technique was used to study the NaCl and O&G effects on aerobic biological treatment of fish canning industrial wastewaters. It was found that above 17.5 g/L of NaCl the inhibition is detectable, but for lower dosages the aerobic biological treatment was not affected. The O&G content proved not to be an activated...
sludge treatment process inhibitor since higher degradation rates were found for higher dosages.

This work showed that, in addition to be useful tools for activated sludge plants design, respirometric tests can effectively contribute to better understand the activated sludge process behavior, allowing early detection of potential inhibitory effects on real wastewater treatment plants, thus avoiding biomass damages.

Acknowledgments

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