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Efficiency of the activated sludge system of an electrical equipment industry

Eficiência do sistema de lodos ativados de uma indústria de equipamentos elétricos

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ABSTRACT

Liquid effluent generation in industrial plants is associated with production processes and employees. Based on the current legislation, these effluents must be subjected to treatment processes in order to be discharged at acceptable levels in receiving waterbodies. The company evaluated in the current study manufactures household and industrial tools and instruments; thus, the aim of the current study is to assess the activated sludge-based effluent treatment system adopted by it. Microscopic analyses of microfauna and biological floc structure, as well as sludge physicochemical and sedimentability analyses, were carried out. The sludge was classified as Pin-Point. Although Arcella sp. prevalence has given sludge a satisfactory clearance feature, the presence of Aspidisca sp. and Trachelophyllum sp. in it has indicated nitrification process and significantly old sludge, respectively. These features combined to low protozoan diversity and lack of micrometazoa have evidenced that sludge quality can be improved. Moreover, sludge overall presented poor settleability. Finally, improvements in the activated sludge system were suggested based on results observed in the current study.

Keywords: Industrial efluent treatment; Microfauna; Liquid effluent

RESUMO

A geração de efluentes líquidos em uma planta industrial está associada aos processos produtivos e aos funcionários. Esses efluentes necessitam passar por um processo de depuração que os adequem a níveis aceitáveis para descarte, em corpos hídricos receptores, exigidos pela legislação vigente. A empresa avaliada neste estudo é fabricante de ferramentas e instrumentos de uso doméstico e industrial. Com isso, o trabalho teve como objetivo realizar a avaliação do seu sistema de tratamento de efluentes por lodos ativados. Foram realizadas análises microscópicas da microfauna e da estrutura do floco biológico, além de análises físico-químicas e de sedimentabilidade do lodo. O lodo foi classificado como Pin-Point. Apesar da predominância de Arcella sp. conferir ao lodo uma característica de boa depuração, a presença de Aspidisca sp. e Trachelophyllum sp. indicam respectivamente, a ocorrência de nitrificação e elevada idade do lodo. Essas características associadas à baixa diversidade de protozoários e a ausência de micrometazoários indicam que a qualidade do lodo pode ser melhorada. Além disso, de forma geral, o lodo apresentou má sedimentabilidade. Por fim, a partir dos resultados, realizou-se a proposição de melhorias.

Palavras-chave: Tratamento de efluente industrial; Microfauna; Efluente líquido

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1 INTRODUCTION

Water contamination with domestic and industrial effluents changes its physical, chemical and biological features and directly affects its quality and use for human consumption. Thus, effluents deriving from anthropogenic activities should be properly treated in effluent treatment plants (ETPs) in order to remove pollutants, minimize environmental damages and protect public health (OLIVEIRA, ARAÚJO and FERNANDES, 2009).

The activated sludge system is widely used as industrial effluent treatment model due to its ability to achieve high organic matter removal rates, as well as because it requires implementation area smaller than that required for other treatment systems. The activated sludge is based on the biochemical oxidation of organic and inorganic compounds found in effluents - in aerobic environment - by a diversified microbial population formed by bacteria, fungi, protozoa and micrometazoa. Bacteria make up the majority of microorganisms present in activated sludge; have the main role of removing the nutrients from the wastewater and in structuring biological flocs (BENTO et al., 2005).

Microfauna composition in activated sludge systems shows process trends concerning the removal efficiency of both biochemical oxygen demand (BOD_5) and suspended solids (SS), sludge sedimentation conditions, aeration level adopted in the system and presence of toxic compounds such as heavy metals and ammonia. Besides, it can point towards the incidence of nitrification and organic overloads, since microfauna is highly sensitive and has fast response to changes in physicochemical and environmental conditions observed in such process (GERARDI, 1986; HOFFMANN and PLATZER, 2000). Thus, treatment efficiency lies on assessing the following aspects: influence of toxic compounds on the herein addressed process, system's ability to remove toxic loads, flocculation capacity, quality of active biomass and the composition of formed flocs (OLIVEIRA, ARAÚJO and FERNANDES, 2009; JORDÃO and PESSÔA, 2005).

The microscopic sludge analysis has shown microorganisms often used to indicate depuration process, effluent quality, age of the sludge and oxygenation. Some of them are found in the Table 1 (CETESB, 1985).

Table 1- Indicator value of common microorganisms found in activated sludge systems (Adapted from CETESB, 1985)

Microorganisms	**Indicator value**
Predominance of flagellates and amoebas	Young sludge, characteristics of early operation or low age of sludge
Flagellates predominance	Lack of oxygenation
Predominance of attached and free-swimming ciliates	Good performance in the depuration process
Presence of *Arcella* (testate amoebae)	Good performance in the depuration process
Presence of *Aspidisca costata* (Free-swimming ciliate)	Nitrification
Presence of *Trachelophyllum* (Free-swimming ciliate)	Old sludge
Presence of *Vorticella microstoma* (Attached ciliate)	Low effluent quality and lack of oxygen in the aeration tank.
Predominance of *Aelosoma* (annelid - micrometazoa)	Too much dissolved oxygen
Predominance of filamentous bacteria	Bulking sludge

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Floc and filament sizes are also microscopically analyzed; small flocs recorded diameter up to 100 μm (Pin-Point), medium-to-large flocs ranged from 100 and 300 μm (ideal) and large flocs were bigger than 150 μm (they could cause sludge swelling) (CETESB, 1985; VON SPERLING, 2012; SANT'ANNA JR, 2010). Ideal flocs are often predominantly medium-to-large sized, firm, round and compact; besides, they present balanced number of filamentous bacteria (CAVALCANTI, 2012).

Therefore, the microscopic analysis of flocs and microfauna found in sludge is an important indicator of system performance and efficiency, since it enables achieving faster responses to purification process conditions than conventional chemical analyses (CYBIS and PINTO, 1997).

According to Von Sperling (2012), temperature influence decreases as sludge gets older in activated sludge systems; therefore, temperature does not cause significant changes in older sludge systems such as the extended aeration activated

sludge system. Such outcome results from the physical removal of a large portion of suspended BOD_5 by floc adsorption, regardless of the temperature.

Microorganism growth is very sensitive to pH variation, since heterotrophic bacteria overall act at pH ranging from 5.5 to 8.5 and achieve optimum growth at pH 7.0. Microorganism response to pH and to other environmental variables in aerobic effluent treatment systems affects the overall behavior of different species, rather than the behavior of a specific group – pH range from 6.0 to 8.0 is the most suitable for these systems. Besides organic matter removal, the most favorable pH to enable nitrification during effluent treatment processes ranges from 7.5 to 8.5. However, it is essential highlighting that pH is also associated with corrosion and fouling issues observed in ETPs (SANT'ANNA JR, 2010).

Sant'Anna Jr (2010) have reported the key role played by dissolved oxygen (DO) in the activated sludge system. DO results from several factors such as microbial respiration rate, temperature, oxygen transfer rate due to aeration, medium composition and amount of oxygen in gas (enriched air, air and pure O_2). Thus, the DO range adopted by effluent treatment system is of approximately 2 $mg.L^{-1}$, although aerobic systems can operate at levels up to 0.5 $mg.L^{-1}$. These rates assure safe temperatures and organic load variations inherent to treatment processes. Higher DO values are not detrimental to the process, but they require greater energy expenditure.

Sludge Volume Index (SVI) monitoring and suspended solid analysis are parameters used to control activated sludge solids. The aim of this monitoring type is to identify the quantity and quality of biological floc formation, since these flocs affect the quality of the clarified effluent and sludge blanket height in the decanter (JENKINS, RICHARD and DAIGGER, 2003).

Finally, the sedimentation stage - which takes place in secondary decanters - is essential to activated sludge processes, since sludge sedimentability and compacting features are closely associated with the structure of flocs formed inside the reactor (VON SPERLING, 2012). According to Sant'Anna Jr (2010), sludge sedimentability is the critical point of activated sludge processes, since the necessary microbial

concentration in the aeration tank cannot be reached without adequate sedimentability. In addition, there may be loss of solids in supernatant stream, a fact that impairs the quality of the treated effluent.

Activated sludge treatment systems may present operational issues capable of affecting the quality of the final effluent. Such issues can result from lack of optimal hydraulic flow conditions, as well as from lack of control over processes or over biological floc formation. Thus, the amount of biomass used in activated sludge systems must be enough to treat the effluent and to remain stable in order to assure optimal system operation conditions (RICHARD, 2003). Therefore, it is essential conducting analysis in the activated sludge system to keep the process stable and efficient. However, studies about, and analyses of, the behavior of microbial populations found in activated sludge remain scarce in Brazil, since knowledge about this dynamics is of fundamental importance to enable the operational control of the process (CYBIS and PINTO, 1997).

Accordingly, the aim of the present study was to evaluate the activated sludge-based effluent treatment system of an electrical equipment industry, based on optical microscopy, physicochemical and sedimentability analyses, in order to investigate its efficiency and to suggest improvements.

2 METHODOLOGY

2.1 Stydy area characterization

The investigated effluent treatment system, which was implemented in 2007, is classified as continuous-flow extended-aeration activated sludge. The system comprises one aeration tank (aerated reactor) and two secondary decanters that operate in parallel.

The investigated ETP receives two types of effluents:

a) industrial effluent - sent to storage tanks after filtration in non-woven fabric; next, it is subjected to dissolved air flotation (DAF) and, finally, to the activated sludge

system. It consists of aluminum and silica, both in suspension, due to the equipment sanding process.

b) domestic effluent - derives from toilets and general cleaning activities performed in the company. It runs through a grid, a septic tank and through an anaerobic filter before it is sent to the activated sludge system.

The effluent flow into the aeration tank can change - the largest effluent volume is generated between 6:00 am and 8:00 pm; peaks are observed at lunch and dinner times due to increased domestic sewage generation. The mean domestic effluent flow is $2m^3.h^{-1}$ ($48m^3.weekday^{-1}$), whereas the mean industrial effluent flow is $12m^3.week^{-1}$ ($2.4m^3.weekday^{-1}$).

Tank aeration happens $24h.day^{-1}$ and sludge-return is continuous at office hours (8:00 am to 5:30 pm). Aeration keeps on operating on weekends and during non-office hours; however, sludge return/discharge pumps do not operate on weekends, so there is no sludge outflow to the pond - outlet piping remains capped in order to maintain sludge and effluent aeration. The sludge excess in the final decanter is sent to drying beds. The volume of sludge disposed of is $3.4m^3.day^{-1}$; it is removed when sludge gets to the recirculation line.

2.2 Sludge collection

Sludge samples were collected at the aerated tank outlet of the activated sludge system. Five collections were performed at alternate days and times in November 2017.

Samples collected from two 5 L plastic gallons were subjected to physicochemical and suspended solids analysis, as well as to sludge sedimentability test. A 50 mL Falcon® tubes (not fully filled and kept under stirring) were used in the microscopic analysis.

2.3 Physicochemical analysis

Sludge samples were filtered for particulate removal purposes and analyzed based on parameters such as pH, temperature and dissolved oxygen, with the aid of a YSI Professional Plus multiparameter probe.

2.4 Microscopic analysis

Biological flocs, filaments and microfauna were analyzed in BIOVAL optical microscope equipped with image analyzer (CMOS 10.0 MP digital camera) in the ISCapture software.

Microfauna was analyzed right after sludge sampling in order to assure that the time interval between sampling and counting procedures was as short as possible (at most 30 minutes).

2.4.1 Analysis of biological flakes and filaments

First, the sludge sample was diluted in saline solution (0.89% NaCl) in a 25 mL beaker (1:10). Next, the diluted sample was added to the Neubauer counting chamber (Optik New - 0.100 mm and 0.0025 mm^2) with the aid of a 3 mL Pasteur pipette in order to be read (CETESB, 1985). The analysis under 10x and 40x objective lens was performed in quintuplicate.

Flocs were measured based on their maximum diameter, whereas filaments were measured based on their number and length. These measurements were taken simultaneously to enable associating the number and length of filaments with specific floc size ranges (CETESB, 1985).

2.4.2 Microfauna analysis

Sludge aliquots (15µL) were visualized under optical microscope, at 100 and 400x magnification for microfauna characterization purposes. Five samples were taken in each collection day. Microorganism groups were identified, counted and photographed; their identification was performed at genus level, based on observations about their morphological features, movement and size (CETESB, 1985).

Microorganism density per mL of sample and two relative frequencies were calculated based on microorganism counting. The first frequency determined the amount (in percentage) of a given microorganism for every 100 microorganisms found ($f_{microorg.-microorg.}$), whereas the second frequency determined the number of days a particular microorganism was observed ($f_{microorg-day}$) within the total of five analysis days (100%).

2.4.3 Industrial efluent analysis

An industrial effluent sample deriving from the electrical equipment sanding process conducted after the non-woven fabric filtration was assessed in microscope to enable characterizing aluminum and silica particles, as well as to identify their presence in the analysis applied to biological flocs formed during the activated sludge process.

2.5 Sludge sedimentability analysis

Sludge Volume Index (SVI) indicate sludge settleability (Table 2) (VON SPERLING, 2012). SVI is defined as the volume occupied by 1 g of sludge after 30 minutes of decantation and it can be calculated through Equation 1.

$$SVI = \frac{H_{30} \cdot 10^6}{H_0 \cdot SS} \quad (1)$$

Where:

SVI = Sludge Volume Index ($mL.g^{-1}$);

H_{30} = height of the interface after 30 minutes (m);

H_0 = height of the interface at time 0 (height of the water level in the settling cylinder) (m);

SS = suspended solids concentration in the sample ($mL.g^{-1}$);

10^6 = conversion from mg to g, and from and mL to L.

Thus, suspended solids (SS) is calculated by Equation 2.

$$SS = \frac{W_2 - W_1}{V}$$

(2)

Where:

SS = Suspended solids ($mL.g^{-1}$);

W_1 = Inicial weight of crucible and filter (mg);

W_2 = Inicial weight of residue, crucible and filter (mg);

V = Sample volume (L).

Table 2 – Range of Sludge Volume Index (SVI) (VON SPERLING, 2012)

Settleability	**SVI**
Very good	0 – 50
Good	50 – 100
Fair	100 – 200
Poor	200 – 300
Very poor	> 300

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Suspended solids ($mL.g^{-1}$) were analyzed based on the methodology suggested by Standard Methods for the Examination of Water and Wastewater (CLESCERI, GREENBERG and EATON, 1998). The aliquot of 2 L of homogenized sludge was added to two beakers (2 L) and the initial sludge height (H_0) was measured with the aid of a ruler in order to find H_0 and H_{30}. The sample remained in the beakers for 30 minutes for sedimentation purposes; next, the decanted sludge height (H_{30}) was measured. This analysis was performed in duplicate.

2.6 Statistical analysis

Data were subjected to statistical analysis in the BioEstat 5.0 software - analysis of variance (one-way ANOVA) and Tukey test ($p < 0.05$) were used to compare floc/filament size, suspended solids and SVI between collection days.

Sludge physicochemical and microscopic parameters were correlated to each other through multivariate analysis (correlation matrix was based on Pearson's correlation coefficient).

3 RESULTS AND DISCUSSION

3.1 Physicochemical parameters

Table 3 presents the values of the physicochemical parameters per collection. Temperature during sludge collection days remained between 25ºC and 27ºC, i.e., it was within the ideal range for maximum microbial activity (SANT'ANNA JR., 2010). This parameter was not correlated to pH and DO concentration (r = -0.10 and -0.36, respectively). According to Von Sperling (2012), temperature does not lead to significant changes in extended aeration activated sludge systems.

Table 3 - Physicochemical parameters of the active sludge system

Collection	Temperature (°C)	pH	DO (%)	DO (mg.L^{-1})
1	26.70	7.34	10.20	0.83
2	25.30	7.73	27.80	2.28
3	27.00	7.87	27.30	2.18
4	25.70	7.72	27.60	2.25
5	26.40	7.81	32.10	2.58

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The parameters pH and DO concentration showed an increasing, mainly, between the first two collections and a strong correlation between them (r = 0.933). The values of these parameters were within the proper operating range, being 6 to 8 pH and the operating range used for DO is approximately 2 mg.L^{-1}. Only the OD in the first collection was below this value, which may be related to a higher rate of purification of organic matter (SANT'ANNA JR., 2010).

According to analyses conducted by Soares et al. (2014), DO level was lower than 0.5 mL.g^{-1}in 87.5% of the cases presenting swollen sludge. This outcome has proved that filamentous bacteria develop better at low DO concentrations (between 0.1 and 0.5 mL.g^{-1}). Thus, it appears that the investigated sludge did not have swelling feature.

Soares et. al (2014) have also stated that the ideal DO range lies between 1 and 3 mL.g^{-1}. This range was in compliance with the satisfactory floc structure found in 73.4% of the sampling events in their study. This finding suggests that non-excessive

oxygen increase implies greater efficiency in the process and better floc formation. Accordingly, DO values recorded in the current study were within the ideal range.

3.2 Microfauna identification and quantification

Table 4 shows the protozoa genera found in activated sludge system, density and relative frequencies. Genus *Arcella* (Figure 1) prevailed in the analyzed sludge, since it was found in 80% of analysis days and represented 92% of microorganisms found in the sludge (Table 4). Individuals belonging to genera *Aspidisca* and *Trachelophyllum* (Figure 1) were also found in the sludge, although at lower densities and frequencies (Table 4).

Table 4 – Protozoa genera found in the active sludge system, densities and frequencies

Genera	**Density (organisms.mL^{-1})**	**f $_{microorg-microog.}$ (%)**	**f $_{microog-day}$ (%)**
Arcella	557	92	80
Aspidisca	43	7	36
Trachelophyllum	15	1	8

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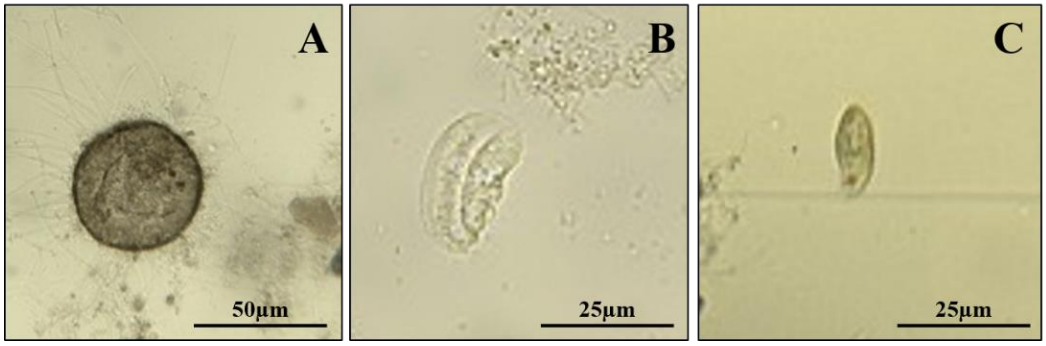
Figure 1 – Microscopy of protozoa found in the active sludge system: Arcella sp. (A); Aspidisca sp. (B); Trachelophyllum sp. (C)



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The predominance of *Arcella* sp. suggests a satisfactory clearance in the system, while the presence of *Aspidisca* sp. and *Trachelophyllum* sp. indicate the occurrence of nitrification and high sludge age, respectively (CETESB, 1985). Nitrification (transformation from ammonia to nitrate) may be related to the pH range found (on

average, 7.61), since, according to Sant'anna Jr (2010), the most favorable pH for the occurrence of nitrification and removal of organic matter is 7.5 to 8.5. The high age of the sludge is characteristic of prolonged aeration systems (VON SPERLING, 2012).

According to Filho (2009), biological systems focused on treating nitrified sewage often require large amounts of oxygen, since the available dissolved oxygen is simultaneously used by heterotrophic organisms responsible for carbonaceous matter removal in aerobic environments (activated sludge systems) and by nitrifying autotrophs.

In addition, activated sludge systems must present bacterial, protozoa and micrometazoan diversity in order to have good quality and greater efficiency, since bacteria, protozoa and micrometazoa play a key role in maintaining the quality of the sludge. Bacteria are the main responsible for carbonaceous matter purification and floc structuring. Protozoa and micrometazoa play an essential role in maintaining bacterial community balance, in removing *Escherichia coli*, as well as in reducing BOD_5 and flocculation (GERARDI, 1986; HOFFMANN and PLATZER, 2000; SIQUEIRA-CASTRO et al, 2016; ZHOU et al, 2006).

Soares et al. (2014) have observed great microfauna diversity during the microscopic analysis applied to the activated sludge system implemented in an industrial ETP. They have found different genera of organisms belonging to groups such as testate amoebae, rotifers, attached ciliates and free-swimming ciliates, which characterized a process presenting old sludge and good purification quality.

Bento et al. (2005) have analyzed the activated sludge system of a domestic ETP and observed approximately 32 microorganism genera, which encompassed representatives of all groups. According to them, global and systemic sludge evaluations play a key role in qualitative analysis. The presence of a single microfaunal species should not be often used as indicative of process performance.

Schlegel, Paul and Jaeger (2016) has investigated an activated sludge system used to treat textile industry effluents and found low protozoa amount in it. According to them, the low frequency of these organisms in the activated sludge may indicate

high toxicity in such environment, which is an adverse condition for the development of several life forms.

Thus, it is necessary increasing microfauna diversity in the investigated sludge to help improving the efficiency of sludge purification processes.

3.3 Characteristics of biological flakes, filaments and sedimentability of sludge

Table 5 presents the mean floc and filament sizes at each collection day. Floc diameter ranged from 39.32 µm to 103.74 µm; most flocs were classified as Pin-Point due to their small size (< 100 µm) and consequent poor sedimentation (Figures 2A e 2B) (CETESB, 1985; VON SPERLING, 2012; SANT'ANNA JR, 2010).

Table 5 - Average size (± standard deviation) of flocs and filaments found in the active sludge system

Collection	Flocs Diameter (µm)	Filament lenght (µm)
1	39.32 ± 14.24[a]	13.02 ± 7.84[a]
2	61.06 ± 31.99[b]	23.84 ± 20.36[a]
3	44.59 ± 24.19[a]	23.98 ± 16.35[a]
4	63.38 ± 25.17[b]	19.24 ± 14.51[a]
5	103.74 ± 76.52[b]	26.29 ± 26.47[a]

Letters indicate significant difference between means by ANOVA and Tukey tests ($p < 0.05$)
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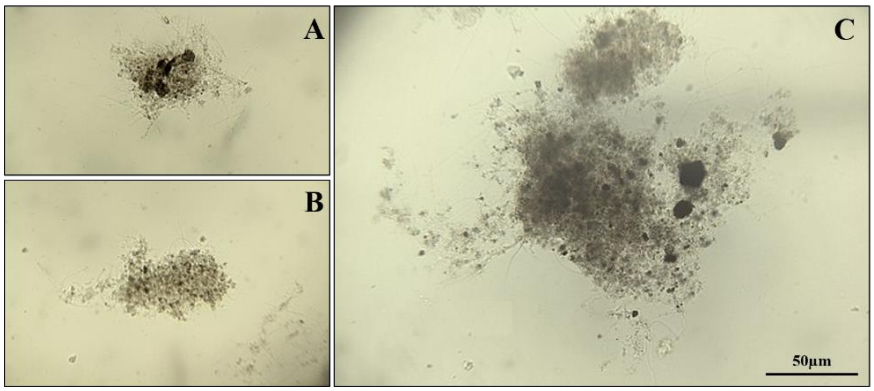
Figure 2 – Microscopy of active sludge flocs observed in first (A and B) and last sample collection (C)



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Flocs presented medium size, whereas filaments presented the largest size in the last sample collection. However, flocs remained relatively dispersed, even after

their size increased. Moreover, they did not present round or compact shape (Figure 2C); therefore, they could not be considered ideal flocs (CAVALCANTI, 2012).

This increase may be related to the dilution and carrying of aluminum and silica caused by the intense rains in the period, due to the large runoff and flooding of the aerated tank, causing loss of effluent / sludge. This is due to the possibility that aluminum and silica are toxic to flake-forming bacteria and filamentous bacteria, which may have been present in greater quantities in the lesser presence of these elements. According to Aguiar and Novais (2002), some heavy metals are highly toxic substances and are not compatible with most existing biological effluent treatments. Madoni et al. (1996) carried out acute toxicity tests of some heavy metals for the protozoan community that inhabit the activated sludge system and found that there are microorganisms more sensitive than others depending on the tested metal.

In addition, Schlegel et al. (2016) noted in their study that the flakes were dispersed and not many filamentous bacteria were found, responsible for the flake structure, combined with the flake-forming bacteria. This dispersed growth is common in industrial effluents because of the toxicity and high amount of organic matter in the effluent.

This explanation is also corroborated by the microscopic identification of aluminum and silica in all samples from the activated sludge system analyzed in the current study.

Figure 3 shows the number of flocs and filaments found in the samples during collection days. The number of flocs ranged from 5 to 18; they were more and lesser frequent in the first and third collections, respectively. On the other hand, the number of filaments ranged from 33 to 111; they were also lesser frequent in the third collection. Based on Pearson's correlation coefficient ($r = 0.85$), these two parameters were strongly correlated to each other.

Figure 3 - Number of flocs and filaments found in the samples during collection days (1-5). The bars represent the standard deviation of the mean and the letters indicate significant difference between the days of collection by ANOVA and Tukey tests ($p < 0.05$)

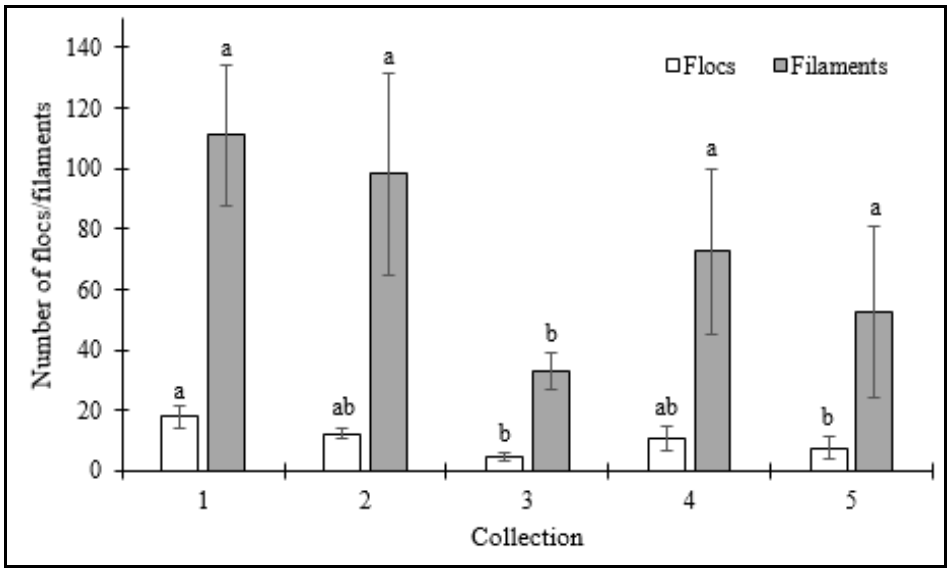

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Table 6 presents the data on SS, SVI and settleability. The highest SS value was observed in the third collection (on average, 2173.33 $mg.L^{-1}$) and the lowest in the first (on average, 511.11 $mg.L^{-1}$). For the SVI, the highest value was in the first collection (on average, 1010.19 $mL.g^{-1}$), and the lowest, in the last (on average, 175.70 m $L.g^{-1}$).

Table 6 - Suspended solids (SS) and Sludge Volume Index (SVI) found in the active sludge system

Samples	**SS** ($mL.g^{-1}$)	**SVI** ($mL.g^{-1}$)	**Settleability**
1	511.11 ± 119.46 [a]	1010.19 ± 8.21 [a]	Very poor
2	656.67 ± 95.63 [a]	933.14 ± 0.00 [b]	Very poor
3	2173.33 ±141.89 [b]	416.43 ± 0.00 [c]	Very poor
4	566.67 ± 197.85 [a]	240.88 ± 0.00 [d]	Poor
5	928.89 ± 271.75 [a]	175.70 ± 4.52 [e]	Fair

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The average number of flakes and filaments analyzed showed a strong correlation with the average values of SVI (0.75 and 0.78, respectively). This behavior

was also found by Hermoso et al. (2006), when analyzing a system of activated sludge for the treatment of effluent from the soft drink industry. The authors observed that when flake structure had a large number of filaments, the SVI values were relatively high and vice versa.

Sludge settleability as a function of SVI ranged from poor to average quality. Such classification corroborates with the presence of Pin-Point flakes, observed under microscopy, which results in poor sedimentation and flotation of the sludge in the secondary settler, causing loss of solids in the aeration tank, increase of solids downstream and reduction of efficiency in the removal of polluting cargo. The fact that the last sample shows better settleability (SVI from 100 to 200 $mL.g^{-1}$) may be related to the larger size of the flakes and filaments found (Table 5).

Hermoso et al. (2006) also observed poor sludge settleability in most of the study and related this fact to the flake morphology. The diffuse structure presented by most of the evaluated flakes is considered an important indication of inadequate sedimentability conditions, where only compact and robust flakes are indicative of good settleability.

3.4 Suggestions for improving the activated sludge system of the electrical equipment industry

The current study has identified some deficiencies in the activated sludge effluent treatment system, such as improper functioning of the recirculation pump, lack of sludge disposal, sludge flotation, poor aeration and pH drops in the aeration pond.

It was suggested to adjust the sludge return rate by keeping the sludge layer in the decanter at approximately 30 to 90 cm to avoid DO and pH decrease, since it influences nitrification. It was also suggested to increase aeration by maintaining adequate DO rate or, whenever possible, by increasing air flow (ACQUA, 2010).

Industrial effluent should not be allowed to enter the process in order to enable microbial diversity increase. In addition, improvements should be done in the

filtration system to avoid the possible toxic effects of aluminum and silica on the microbial community found in the sludge.

Water capture should be implemented on the sides of the aeration tank (through channels) to help minimizing the risk of floods and to prevent rain-borne water from flowing directly into the system.

Sludge settleability can be improved by checking whether the aeration tank is close to the underfeed condition due to the presence of old sludge in the system. Thus, it is necessary increasing the discharge rate to up to 10% a day until the process gets close to the normal operation parameters set for average organic load values, as well as adding coagulants such as aluminum sulfate, ferric chloride or Polymer to enable floc sedimentation, whenever necessary (ACQUA, 2010).

4 CONCLUSIONS

Based on the evaluation of the activated sludge system, it was possible classifying the sludge as Pin-Point. Despite the prevalence of *Arcella* sp. in the sludge has indicated good clearance, the presence of *Aspidisca* sp. and *Trachelophyllum* sp. has indicated the incidence of nitrification and old sludge, respectively. These features, in association with low protozoan diversity and lack of micrometazoa, have indicated that sludge quality can be improved. In addition, sludge overall presented poor sedimentation.

Microfauna and floc characterization analyses were extremely useful to help better understanding and optimizing the process taking place in the activated sludge system, since system evaluation allowed determining and quantifying microorganisms found in it, as well as qualifying biological flocs formed during the process. In addition, microfauna analysis helped identifying the possible origin of adversities taking place in the treatment process and, based on such identification, the company was able to make improvements focused on increasing its efficiency and on decreasing the incidence of setbacks in the industrial effluent treatment system. Therefore, the

current study has contributed to improve the efficiency of activated sludge effluent treatment.

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