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Physical-Chemical Characterization of Solid Waste Generated in the Water Industry: Case Study of the Water Treatment Stations of the Metropolitan Region of Recife

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ABSTRACT

The objective of this research is to characterize the solid waste, commonly known as sludge, from the water treatment industry. Six main water treatment plants (Alto do Céu, Botafogo, Caixa d'água, Gurjaú, Suape and Tapacurá) were selected from the Metropolitan Region of Recife, managed by Companhia Pernambucana de Saneamento. Nine samples were collected in the eleven month period in the discharge of the sludge from the decanters. These samples were characterized physico-chemically, based on the methodology of the Standard Methods for the Examination of Water and Wastewater (2012). The results indicated average humidity of 93%, average COD around 30 g/L and BOD of 4.5 g/L, indicating sludge of low biodegradability. The average values of total solids were 72 g/L, with 75% corresponding to fixed residues and 25% to volatiles. High concentrations of aluminum (1000 mg/L) were observed, due to the use of aluminum sulphate as a coagulant, and iron, around 500 mg/L. This study assists the manager in the decision making of the sustainable management of the sludge, mainly in relation to the final disposal

Keywords: water treatment plant, characterization, sludge

Introdução

The Water Treatment Plant (WTP) has a similar operation of an industry, whose raw materials (raw water) is transformed into a final product (drinking water) directed to human consumption (Oliveira et al., 2015). This water post-treatment must meet standards of potability established in Brazil by the Federal Decree No. 2.914/2011 of Ministry of Health (BRASIL, 2011). According to Tavares (2016), a WTP involves units that are equipped with operations and unit processes for the removal of certain impurities present in the raw water. These impurities are called waste or commonly called slugde of WTP.

According to NBR 10.004 (ABNT, 2004) and the National Solid Waste Policy (BRASIL, 2010), the WTP sludge fits in as non-inert solid residue. These residues are constituted by a mass of organic and inorganic particles, dense and viscous, that can become a potential source of pollution if it does not have prior treatment to its destination (SILVA et al., 2012). Basically they are generated in the decanters and in the washing operation of the filters (FERREIRA FILHO; ALÉM SOBRINHO, 1998). However, in a detailed way, they can be produced in the processes of coagulation, flocculation, filtration and oxidation of surface waters, removing turbidity, color, bacteria, algae, organic compounds and often iron and manganese. The most commonly generated residues are those produced by aluminum and iron salts used in coagulation. Another type of sludge generated results from the addition of calcium oxide and sodium hydroxide which are added to remove calcium and magnesium from hard water. Usually most of these wastes belong to one of the following categories: (i) Particulate and colloidal matter, removed from the raw water in decanters and filters, such as clay and silt, and inert material from the chemical treatment, such as calcium oxide (CaO) debris; (ii) Soluble substances such as iron, manganese, calcium and magnesium, which are brought to the form of insoluble precipitate by oxidation or pH adjustment; iii) Precipitates formed by the application of chemical products, such as aluminum and iron complex hydroxides (Al (OH) 3 and Fe (OH) 3); and iv) Materials used in the treatment units, which periodically must be replaced when their useful life ends, such as activated charcoal in powder or granules, filters, etc. (TAVARES, 2003).

The physico-chemical and microbiological characteristics of WTP sludge can vary acording to the water treatment process and some factors such as raw water quality, treatment technology, coagulation characteristics, flocculation and filtration, the use of oxidant, the method of cleaning decanters and filters, among others (DI BERNARDO et al., 2011; GHEYI, 2012). According to Fonollosa et al. (2015), in addition to the high humidity content, generally higher than 95%, WTP sludge may contain high concentrations of organic matter, solids, metals, salts, cyanobacteria and microorganisms, among other organic and inorganic substances. Sun et al. (2015) verified high concentrations of total iron in WTP sludge in Australia, whose coagulant was ferric chloride. In addition, other metals (Al, Mn, S, Zn, Pb, Ni, Cu and Cd) were found, however, in lower concentrations. The levels of nitrogen, phosphorus and organic matter in COD form were 11.9; 1.1 and 352 g kg-1 dry sludge, respectively. Ma et al. (2014) verified in the WTP sludge cyanobacteria and toxic byproducts of the cellular lysis of these organisms, such as microcystins that have serious implications for human health. Zhou et al. (2015) when analyzing the WTP sludge obtained a concentration of 8 x 105 NMP 100 mL-1 of total coliforms, in addition to an average COD of 307 mg L-1. The coagulant used was aluminum polychloride and ferric chloride. Cerqueira et al. (2014) observed the presence of 21 drugs and at least 6 substances used in personal hygiene products in the WTP sludge of the city of Rio Grande - RS. Among the drugs were perceived the presence of the antibiotics clarithromycin and metronidazole, the antihypertensives chlorthalidone and propranolol, antidepressants azathioprine, amitriptyline and carbamazepine, besides others. Among the group of hygiene products are benzphenone and triclosan. Fonollosa et al. (2015) reported concentrations of silver, antimony, ruthenium, cobalt, cesium, lead, beryllium, bismuth, uranium, polonium, thorium, radio, among other metals in WTP sludge.

In addition to WTP sludge quality, another challenge is the amount of waste generated daily by the treatment system. Mogami (2013), founds it is estimated that for each 1m³ of treated water, 20 g / m³ of solid waste is generated. According to IBGE (2010), of the 5,564 Brazilian municipalities only 2,098 have WTP, which total is about 7,500 stations. These produce, on average, 56,739,726 m³/day of treated water, generating sludge whose final disposal occurs about 60% in soils and water bodies without any previous treatment. According to Achon et al. (2013), this inappropriate disposal is contrary to the current legislation, as it causes negative environmental impacts, in addition to violating the laws of disposal of solid waste and the discharge of effluents into water bodies. This is a problem that affects all Brazil, especially the North and Northeast of the Country.

Taking into consideration all that has already been written, the previous characterization of the WTP sludge assists the manager in the proper management of the waste, especially in relation to the final disposal, in order to seek alternatives that minimize the environmental impact generated in the environment due to inadequate disposal. In this way, the present research seeks to characterize the sludge generated in the six main WTP of the Metropolitan Region of the Recife (MRR), proposing this as basic and fundamental step to support the decision making of the service managers.

Material e Métodos

The experimental work was developed using solid phase samples from the six main water treatment stations (WTP) that supply the population of the Metropolitan Region of Recife (MRR), which are managed by Companhia Pernambucana de Saneamento (COMPESA). In each WTP, 9 (nine) samples were collected in the 11 (eleven) month period at the point of discharge of the sludge accumulated in the decanters (Figure 1). At each point, 02 (two) liters of sample were collected in a plastic bottle. Sampling occurred at different times of the year, so that it contemplated the seasonal variations of MRR. The description of the collection points is presented in Table 1.

Figure 1 - Collection points of WTP Gurjaú. Discharge drain from the decanter sludge.

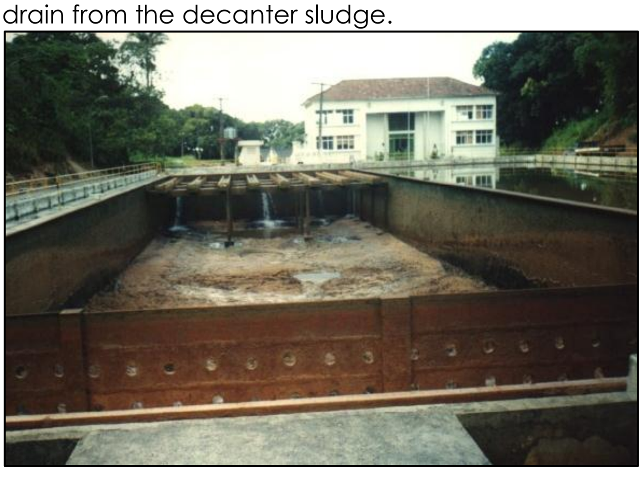


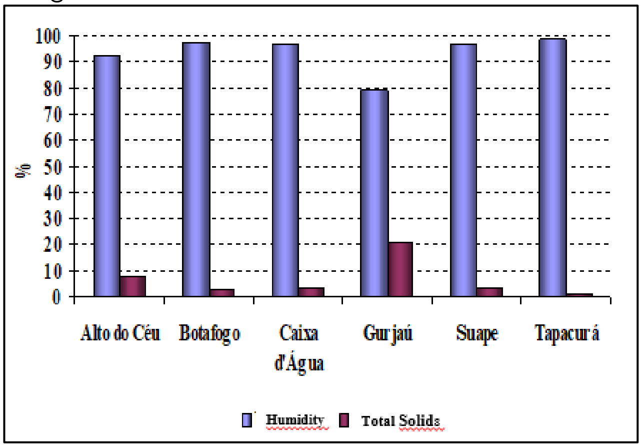
Table 1 - Description of collection points.

WTP	Collect point
Alto do Céu	In the discharge pipe of the decanter
Botafogo	In the discharge pipe of the decanter
Caixa d'Água	In the discharge pipe of the decanter
Gurjaú	In the discharge pipe of the decanter
Suape	In the discharge pipe of the decanter
Tapacurá	In the discharge pipe of the decanter

The field sampling was carried out observing the favorable conditions of the local time (sunny weather) so that the results contemplated the real conditions of the object of study. After in situ sampling, the samples were labeled and the field measurements of the following parameters were carried out: pH, temperature, electrical conductivity and salinity. Then, they were conditioned and sent for laboratory analysis.

The main physical-chemical parameters analyzed were solids (total fixed and total volatiles and fixed and volatile suspended), chemical oxygen demand (COD), biochemical oxygen demand (BOD), total phosphorus, sulfate, chloride and metals, based on the methodology described in the Standard Methods for the Examination of Water and Wastewater (2012), as well as the procedures of collection, preservation and pretreatment of the samples. The analyzes were carried out in the Laboratory of Environmental Sanitation (LSA-CTG-UFPE) and in the Laboratory of Emission Spectrometry (ICP-CTG-UFPE).

Figure 2 - Moisture content and total solids in the sludge from the decanters in the WTPs.



Resultados e Discussão

Characteristics of sludge from the decanters

The residues generated in WTP are produced by coagulation, flocculation, filtration and oxidation of surface water to remove turbidity, color, bacteria, algae, organic and inorganic compounds such as iron and manganese.

Aluminum sulfate is the coagulant used in all WTPs managed by Compesa, resulting in a brown-colored sludge with viscosity and coloration reminiscent of liquid chocolate. When iron salts are used as a coagulant, the sludge usually turns reddish-brown and presents flotation difficulties. This fluid state is a function of high humidity. The average humidity content of the sludge from the six WTPs was 93%, as shown in Figure 2. Studies by Monteiro (2014) and Tavares (2016) found humidities around 95% in the WTP sludge of Botafogo/PE.

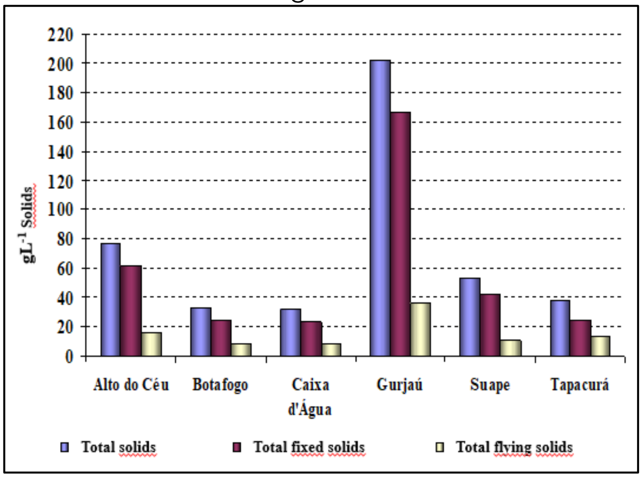
The WTP Gurjaú presented denser sludge, with lower percentage of water in its structure, whereas WTP Tapacurá generated wetter sludge from the ETA studied. This fact may be related to WTP operation, as it relates to the dischargers of the decanters. WTP Gurjaú eventually discharges, while WTP Tapacurá has a rigid control of its discharges that are done daily. This procedure decreases the solids concentration in the sludge.

Cordeiro (1999) points out that the range of solids may be 0.1 to 1%, when removal occurs at small intervals. However, when this interval is more than 20 days, they even have concentrations biger than 2.5%. According to Achon et al. (2013), in Brazil, the frequency of sludge removal in the decanters of full-cycle WTPs is usually performed at long intervals, and may reach months when manually performed. This practice can generate an accumulation of residues with a high concentration of organic and inorganic contaminants, besides making difficult the removal and final disposal of the sludge, making this step costly.

The graph of Figure 2 shows average percentages of 1.1% solids for WTP Tapacurá and 21.3% for WTP Gurjaú, which generally passes for a period of 120 days without discharges. The total average solids were above 6,000 mg/L. The WTP Gurjaú showed a higher concentration of solid in its sludge, around 200 g/L, while the others present values around 50 g/L. The values of solids found in this research were higher than those obtained by Mattos and Girard (2013), Monteiro (2014) and Tavares (2016), which obtained solid concentrations of 488 mg/L, 3,224 mg/L, and 350 mg/L , respectively.

According to Richter (2001), the total solids content in the settling tank ranges from 1 to 40 g/L, 75-90% of which is equivalent to fixed solids, and 20-35% to volatile compounds. The average percentages of fixed and volatile solids in the analyzed sludge were 75% and 25%, respectively. It was verified that this residue is composed mostly by inorganic material, as shown in Figure 3. These values are in agreement with the study done by Mattos and Girard (2013) in WTP Bologna/PA, whose sludge had a more inorganic characteristic than With respective values of total fixed solids and total volatile solids of 2,221 mg/L and 1,055 mg/L, respectively.

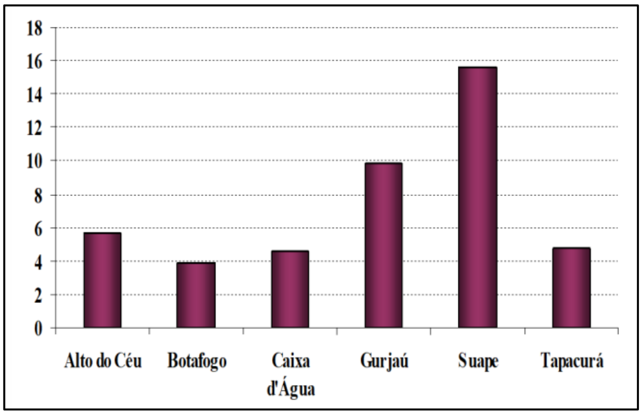
Figure 3 - Concentration in g/L of the total, fixed and volatile solids in the sludge of WTP's decanters.



The average COD concentration of the WTP studied was 29,989.25 mg/L, with WTP Suape having the highest concentration of 51,109.1 mg/L and the WTP Caixa d'água with the lowest value of 7,091.5 mg / L. The average BOD was 4 498.87 mg/L. WTP Tapacurá obtained maximum BOD (10,200.3 mg / L) and WTP Alto do Céu a minimum BOD (2,129.5 mg/L) in the study. The COD/BOD ratio of WTPs ranged from 4 to 16, indicating a sludge of difficult biodegradability. According to Sales (2003), COD/BOD ratio higher than 4 indicates low biodegradability of the residue.

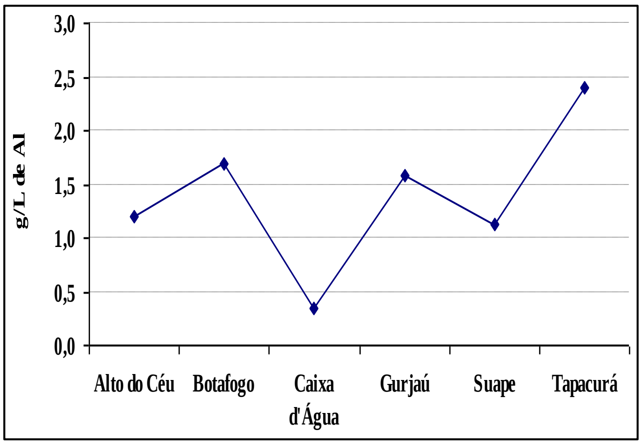
A study carried out by Gervasoni (2014) showed COD values of 5,347 mg / L, BOD of 1,996 mg/L and the COD/BOD ratio resulted in approximate values of 5, which indicates composition of the mostly inorganic sludge. Figure 4 illustrates the relation between BOD and COD in percentage of the sludge from WTP's decanters.

Figure 4 - Relation COD/BOD of sludge in reservoir of sedimentation of WTP.



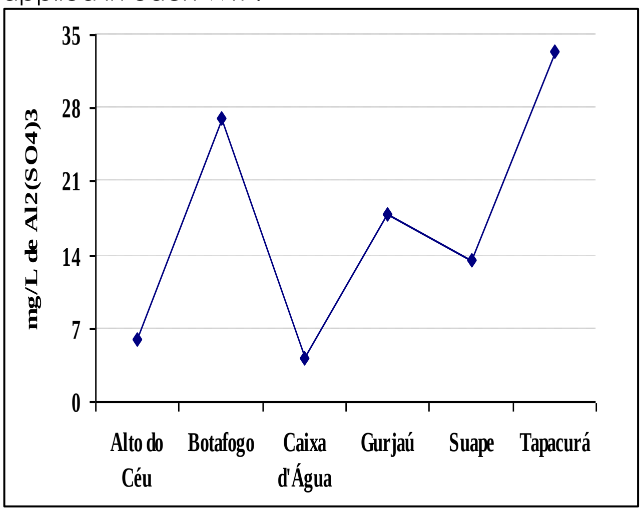
Belo et al. (2016), found the period of accumulation of solids in conventional decanters without mechanical removal is usually quite long, reaching months. Thus, the emergence of anaerobic conditions in the mass of accumulated sludge is favored. A possible consequence of these conditions is the dissolution of metals present in the sludge. Several metals have been found in this work: Al, Ca, Fe, Mg, Cr, Cu, Mn, Ni and Zn. Aluminum was found to be quite high, averaging 1 g/L, due to the use of aluminum sulphate as a coagulant in WTP. Figure 5 shows the concentrations obtained in the WTPs studied.

Figure 5 - Concentration of the aluminum in sludge of WTP's reservoir of sedimentation.



The concentration of aluminum is quite variable in the sludge, as it depends on the quantity and quality of the raw and treated water, and the dosage of the aluminum sulphate used in each season (Araújo et al, 2015). The WTP Caixa D'água treats 200 L/s of water and presents a low aluminum content, when compared to WTP Tapacura, which treats 3700 L/s. However, the application of aluminum sulphate is not only due to the quantity of water treated, but also to the quality of water. A study carried out by Tavares (2016), pointed out that the aluminum concentration in the WTP Mangueira was around 700 mg/L. Tartari et al. (2011) also verified high concentrations of aluminum in the Tamanduá/PR WTP sludge. Araújo et al. (2015) found a concentration of 386.39 mg / kg of aluminum in the sludge generated at WTP Meia Ponte/GO. Figure 6 shows the average amount of aluminum sulphate applied in each WTP during the research period.

Figure 6 - Average dosage of aluminum sulphate applied in each WTP.



In addition to aluminum, iron had high concentrations in the studied sludges, with an average value of 465.25 mg/L. The maximum and minimum values were observed in WTP Alto do Céu (1,397.9 mg/L) and Caixa d'água (22.2 mg/L). The presence of iron in the sludge from the decanters is a result of the concentrations of this metal present in the raw water, besides being one of the constituents of the aluminum sulphate, the main coagulant used by Compesa, whose composition presents 0.9% Fe_2O_3. Therefore, for each gram of aluminum sulphate applied in the treatment of water, 3.15 mg of iron is inserted. Araújo et al. (2015), also verified high iron concentrations in the WTP Meia Ponte/GO sludge, with a value of 212.47 mg/kg. Figures 7 and 8 respectively illustrate the concentrations of iron in the raw water and in the sludge from the WTPs decanters studied.

Figure 7 - Concentration of iron in the raw water of WTP.

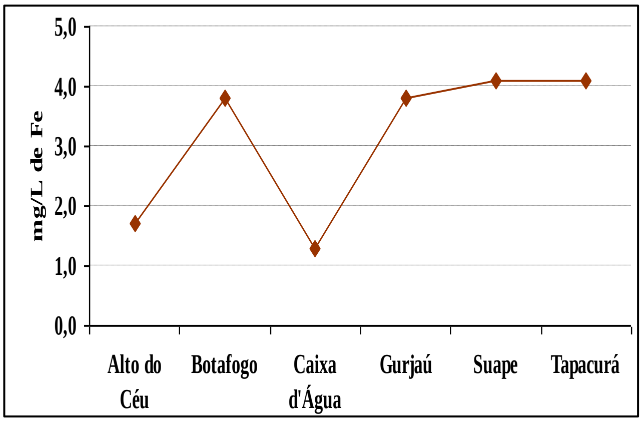
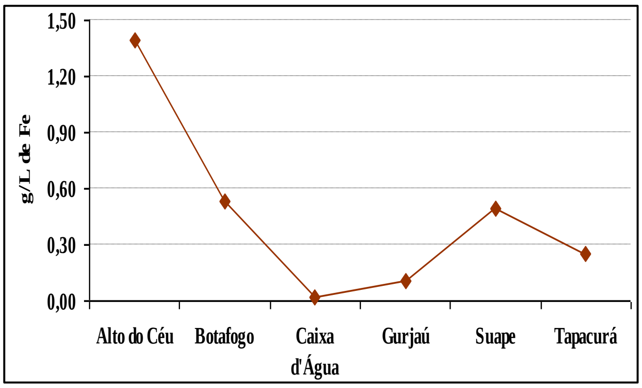


Figure 8 - Concentration of iron in the sludge of WTP decanters.



Conclusões

The characteristics of the solid waste generated in the WTP are directly related to the quality of the raw water treated by the WTPs of the RMR, as a function of it that the quantity of the various chemicals used in the treatment is established.

The residues produced in the WTP decanters presented a brown color with pasty viscosity. This semi-fluid state is due to the high average humidity that was around 93%. Among the WTPs studied, that of Gurjaú presented a residue with a more solid consistency, due to a lower humidity, around 78%. The solid sludge generated in the decanters of the WTP of the MRR together showed an average COD of around 30 g/L, while the average BOD was 4.5 g/L, indicating that the biodegradability of this residue is low. Another indication of low biodegradability was the results of total solids, which presented average values of 72 g/L, of which 75% corresponded to fixed residues and 25% to volatiles.

The decanter residues have in their composition large concentrations of aluminum, due to the use of aluminum sulphate as a coagulant. The average values of aluminum found for these WTPs were 1000 mg/L. These dumps with high amounts of aluminum are one of the major environmental problems caused by the water industry. Iron was another metal that presented high values in this residue, around 500 mg/L.

The study of the waste characterization generated in the production processes of the water industry is essential to assist the manager of the service regarding the adequate management of this waste, besides alerting him to the possible environmental impacts that its inadequate disposal causes to the environment.

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