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Atividades Realizadas na Universidade Contribuem para a Contaminação da Água da Sanga Lagoão

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RESUMO

O lançamento de efluentes sem tratamento é um dos maiores problemas relacionado à poluição das águas em áreas urbanas, com impactos negativos à saúde pública e ao meio ambiente. Dessa forma, o objetivo do trabalho foi avaliar a qualidade da água de um pequeno afluente da Sanga Lagoão do Ouro que nasce no Campus Central da UFSM, drena água de área experimental agrônômica e de grande número de prédios e recebe os efluentes da CEU-II e do RU Central. O monitoramento foi realizado em dois pontos no arroio (AR1 e AR2) e em dois pontos no dreno que leva efluentes até o arroio (AD1 e AD2). Adicionalmente foram amostrados efluentes de uma ETE por zona de raízes instalada em um dos blocos da CEU-II. Foram avaliados os parâmetros pH, OD, temperatura, condutividade, turbidez, DQO, DBO, coliformes totais, *Escherichia coli*, P total, COT, NT, metais totais e metais dissolvidos. A água do arroio sai da área agrícola já com altos teores de P, Al e Fe dissolvidos e valores de DBO acima dos limites permitidos pela legislação. Os pontos AD1 e AD2 destacaram-se como fontes pontuais de contaminação e apresentaram elevada carga orgânica, com características de efluente bruto. A ETE mostrou-se eficiente na redução da turbidez, DBO, DQO e dos teores totais de Cu, Zn e Fe. Assim, a água do arroio está sendo poluída pelas atividades da universidade, principalmente, pela ausência de tratamento dos efluentes gerados na CEU-II e no RU.

Palavras-chave: qualidade da água, efluente, contaminação.

University Activities Contributed to Sanga Lagoão Water Contamination

ABSTRACT

The release of untreated effluents is one of the major problems associated with water pollution in urban areas, with negative impacts on public health and the environment. Thus, the objective of this work was to evaluate the water quality of a small tributary of Sanga Lagoão do Ouro, which was born in the UFSM Central Campus, drains water from an agronomic experimental area, and a large number of buildings and receives effluents from the university student house (CEU-II) and the university restaurant (RU). Monitoring was performed at two points in the stream (AR1 and AR2) and at two points in the drain that takes effluents to the stream (AD1 and AD2). In addition, effluents from one ETE per root zone installed in one of the CEU-II blocks were sampled. Parameters such as pH, DO, temperature, conductivity, turbidity, COD, BOD, total coliforms, *Escherichia coli*, total P, TOC, TN, total metals and dissolved metals were evaluated. The stream water leaves the agricultural area with already high levels of dissolved P, Al, Fe and BOD values above the limits permitted by the law. AD1 and AD2 stood out as point sources of contamination and presented high organic load, with characteristics of crude effluent. The ETE was efficient in reducing turbidity, BOD, COD as well as the total Cu, Zn and Fe contents. Thus, stream water is being polluted by university activities, mainly because the effluents generated in the CEU-II and RU are not treated.

Keywords: water quality, effluent, contamination.

Introduction

The discharge of untreated effluents is one of the major problems associated with water pollution, especially those of domestic origin, because it is the sanitation service with the greatest coverage deficit in Brazil. The increasing demographic and industrial expansion of the last decades, even close to the sources, has provided and increased the loads of nutrients as well as organic and inorganic substances released into water bodies and soil (Araújo, 2013). The disposal of untreated effluents from local domestic systems can lead to contamination of soil and groundwater with consequent impacts on public health and the environment (Tanner et al., 2012), thereby compromising the quality and quantity of water available in rivers, lakes and underground reservoirs (Araújo et al., 2015).

Numerous human activities have negative impacts on the receiving body, such as the removal of vegetation from the headwaters of the rivers, the cultivation of crops and pastures, the breeding of animals in inappropriate places, the application of agrochemicals, the inadequate disposal of solid wastes and domestic liquid effluents (Madruga et al., 2008). These daily activities generate pollution by point and diffuse sources around rivers, cause an environmental imbalance in water quality and maximize the concentration of pollutants in the water course (Souza et al., 2015). Thus, many countries around the world face problems with drinking water shortages (Tanner et al., 2012).

In Brazil, great concern is still centered on the environmental and health problems caused by macro pollutants; since, according to data from the Diagnosis of Water and Sewage Services - 2013, the population attendance rate with the sewage collection network in Brazil is only 48.6%. As for sewage treatment, only 39% of all sewage generated in the country receives some type of treatment (SNIS, 2014). It is worth mentioning that, when present, treatment usually occurs centrally in large treatment plants. However, a significant portion of the Brazilian population inhabits small communities or rural communities that are far from large centers and do not have access to basic sanitation services (Decezaro, 2016).

Thus, lack of sanitation produces vulnerable environmental situations, especially in areas occupied by the poorest social segments of

the population (Araújo et al., 2015). In Rio Grande do Sul (RS), the municipality of Santa Maria had an estimated population of 277,309 inhabitants in 2016, and the water supply system served 252,516 inhabitants (IBGE, 2017). The sanitary sewage system served 119,152 inhabitants, representing 45.64% of the population of Santa Maria (PMSM, 2015).

The villages surrounding the Federal University of Santa Maria are yet to have a sewage collection and treatment system, hence part of the effluents are discharged into tributaries of Sanga Lagoão do Outro that passes the university campus area. Also, in the University Campus, there are several small tributaries that cross areas of high anthropogenic vulnerability thereby becoming contaminated as a result of enormous human movement as well as academic and research activities. At least three critical points can be highlighted: 1) areas of agricultural experimentation, 2) University Restaurant (RU) and University Student House (CEU-II), whose effluents are not properly treated and are released into water bodies or the soil surface. There is only primary treatment by septic tank followed by the use of an anaerobic filter, located about 30.0 m from the point of discharge (Araújo et al., 2015). Residual wastewater from other UFSM sites is drained by a main sewage network, which passes through the septic tank-filter system, and is then discharged into a river drainage.

The risks of contamination of groundwater and of the population have resulted to increased research on contamination by static systems for the treatment of domestic sewage (septic tanks), mainly those that have a disposal stage in the soil and serve as an integral part of the process (Oliveira and Von Sperling, 2011; Foster et al., 2011). Recently, the UFSM installed an experimental station for the treatment of domestic effluents, with a Vertical Flow Constructed Wetland (VFCW). VFCWs are regarded as an effective alternative for effluent treatment since they can remove pollutants and produce better quality effluent, representing a low cost option, improved environmental value and effectiveness in the removal of contaminants (García and Corzo, 2008; Bohórquez et al., 2017). Experimental VFCW consists of a tank of 18 m³, whose space is filled with three layers of brittle stones, on which are planted about 200 seedlings of

Canna spp. Plant roots and stones (root zone treatment), through the action of biofilms, have the capacity to retain part of the solid waste, functioning as filter elements of the sewage, which is dumped into the tank by means of a conduit (Decezaro, 2016). Since the experiment is research-oriented, VFCW has the ability to treat a sample as equivalent to the sewage produced by only 10 people out of more than 1,700 students residing in CEU-2 (undergraduate students) and CEU-3 post graduate students).

Some studies have already been carried out on the soil, as well as the surface and groundwater of the UFSM Campus (Moreira, 2005; Angnes and Silveira, 2006; D'Ávila, 2009; Reckziegel, 2012; Araújo, 2013; Araújo et al., 2015), all of which emphasize that the University's natural resources face significant quality loss, a reflection that is perceptible by its visual appearance and the formation of gases with unpleasant odor. Much of UFSM's environmental liability comes from periods prior to the law, when individual wastewater treatment systems were sufficient for the situation. However, with the continuous and accelerated growth of the academic population after 2003, the institution has not developed an

infrastructure that would accompany this demand. Thus, the current effluent treatment systems are inadequate to handle the reality of water consumption and the production of liquid effluents (Reckziegel, 2012; Araújo et al., 2015).

In this sense, the general objective of this work was to evaluate the water quality of a small tributary of Sanga Lagoão do Ouro, which is born on the UFSM Central Campus, drains water from an agronomic experimental area, a large number of buildings and receives effluents from CEU-II and the University Restaurant (RU). This study also aimed to evaluate VFCW's efficiency in mitigating potential polluters of domestic effluents.

Materials and methods

Area of study and sampling

This work was developed at the UFSM Central Campus in the municipality of Santa Maria, RS and the monitoring was carried out in two points of the effluent stream of Sanga Lagoão do Ouro; at two points in the drain that carries effluents to the stream and at two points of ETE per root zone installed in one of the CEU-II blocks (Figure 1).

Figure 1. Area of study and location of points of water and effluent sampling at UFSM, Santa Maria, RS.

Two points of water sampling were determined in the stream, the first being AR1, located after the agricultural area, before the beginning of the constructed area of the University, in the middle of the forest, but that drains water

which flows past the agronomic experimental area. The second one, AR2, was located at the entrance of the viaduct, in front of building 42, before the entrance of the effluents from the RU and CEU-II.

Point AD1 is an effluent discharge area of the RU and some CEU II buildings. The effluent receives treatment through a septic tank followed by the use of an anaerobic filter, located about 30 m from the dumping point and flows for about 30 m, until reaching the area of accumulation in the soil. At point AD2, it is probable that untreated sanitary sewage dump occurs, thereby presenting a characteristic feature. This point also represents the output of the rainwater drainage system. These two points are part of an area of approximately 1700 m², where the final effluent discharge takes place directly on the soil surface, flowing through preferential flow zones until reaching Sanga Lagoão do Ouro. In addition, the efficacy of an experimental ETE, implemented for the treatment of a portion of domestic effluents generated in building 35 of CEU II (ETE1 and ETE2, with a flow rate of 1,500 L / day) was monitored. The system consists of a primary treatment with septic tank, an anaerobic filter and a secondary treatment

with VFCW. In the ETE, two points of domestic effluent sampling were designated: the point EF1, at the outlet of the equalization tank, consisting of the raw effluent, after primary treatment and, the point EF2, constituted by the effluent exiting the VFCW, after treatment in the root zone. These two points were used to evaluate the efficiency of the VFCW in the removal of organic and inorganic compounds present in the effluents before they are disposed in the soil (Figure 2).

Two samplings were carried out on April 11, 2016 (air temperature equal to 27°C) and May 2, 2016 (air temperature equal to 22.6°C), both in the morning. The water and effluent samples were stored in 1.0 L PET plastic containers. For the determination of coliforms, water and effluents were collected with sterilized plastic containers having a capacity of 250 mL. During sampling, the samples were kept refrigerated in a polystyrene box for preservation.

Figure 2. Water and effluent sampling sites at UFSM, Santa Maria, RS. (a) AR1; (b) AR2; (c) AD1; (d) AD2; (e) EF1; (f) EF2.

Physico-chemical and microbiological characterization

Parameters such as pH, dissolved oxygen (DO), electrical conductivity (EC) and temperature were determined at the sampling sites using a previously calibrated Multiparameter Meter HI 9829 equipment. In addition, the following parameters were determined: turbidity, Chemical Oxygen Demand - COD, Biochemical Oxygen Demand - BOD, total coliforms, *E. coli*, total phosphorus (P), total organic carbon (TOC), total nitrogen (TN), total metals and dissolved metals. The analytical procedures followed the Standard Methods for the Examination of Water and Wastewater (APHA, 2012), with some adaptations.

The determination of COD was performed by digestion in a digestion block using 2 mL of sample, 1.5 mL of 0.1 N potassium dichromate, 3.5 mL of $\text{H}_2\text{SO}_4 + \text{Ag}_2\text{SO}_4$ solution at a temperature of 150°C. At the end of digestion, titration was performed with 0.0125N ferrous sulfate until a red coloration was obtained. BOD determination was performed by the manometric method, using amber flasks, in which pre-determined sample volumes (according to the expected BOD scale) were added, capped and connected to B.O.D. Sensor System 10. Samples were incubated for 5 days at 20°C with continuous shaking. For the determination of total coliforms and *E. coli*, 5 dilutions (10^{-1} , 10^{-2} , 10^{-3} , 10^{-4} and 10^{-5}) were carried out from 1 mL of crude sample, with each dilution being composed of 5 replicates containing a FLUOROCULT culture medium. After the dilutions, the samples were incubated in an oven for 36 h, at a temperature of 35 to 37°C. The number of total coliforms was counted, verifying the number of tubes that had their coloration altered in each of the dilutions. The number of fecal coliforms (*E. coli*) was counted in the tubes which presented blue green coloration, from the irradiation of UV light. Using the statistical table, the most probable number of total and fecal coliforms per 100 mL (MPN 100 mL⁻¹) was found.

The TOC and TN determinations were performed using a TOC autoanalyzer. The extraction of Total P was carried out after digestion of the samples in a nitroperchloric digester block, following the method of Silva (2009) from 10 ml of liquid sample and 4 ml of $\text{HNO}_3 + \text{HClO}_4$ mixture (3: 1). To obtain the P levels, the method of Murphy and Riley (1962) was applied, using an alkaline medium and paranitrophenol as indicator. The reading was performed on a UV-Visible SP 1105 spectrophotometer, set at a wavelength of 882 nm.

The dissolved and total metals were determined: silver (Ag), aluminum (Al), arsenic (As), boron (B), barium (Ba), beryllium (Be), calcium (Ca), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), potassium (K), lanthanum (La), lithium (Li), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), antimony (Sb), selenium (Se), silicon (Si), strontium (Sr), titanium (Ti), thallium (Tl), vanadium (V) and zinc (Zn), by Inductively Coupled Plasma Optical Emission spectrophotometry (ICP-OES). For the determination of dissolved metals the samples were filtered on a quantitative filter paper of 0.22 µm. For the determination of total metals, the samples went through microwave digestion before the acid digestion process. This study utilized 20 mL of sample, 1 ml of nitric acid and 0.5 ml of hydrochloric acid, with a 30 min ramp time, 10 min digestion time, at a temperature of 175°C.

The parameters of the effluents collected at the points EF1, EF2, AD1 and AD2, (were thrown on the soil and with subsequent drainage and infiltration into Sanga Lagoão do Ouro), were discussed according to the law that deal with the disposal of effluents directly into the soil. The CONAMA Resolution No. 357/2005 (BRASIL, 2005) and its update, Resolution No. 430/2011 (BRASIL, 2011), which provides for the conditions and standards for effluent release, only state that the effluent disposed in soil should not cause any damage to surface and ground water. The same situation occurs for the state legislation defined by the Consema Resolution No. 128/2006 (BRASIL, 2006), which establishes the emission standards for liquid effluents for emission sources that discharge their effluents into surface water in Rio Grande do Sul (RS), without considering the disposal of effluent into the soil.

The data obtained for the samples collected at points AR1 and AR2 were compared with the determinations of CONAMA Resolution No. 357/2005, as they fall into Class 2 (waters destined for human supply, after conventional treatment, protection of aquatic communities; recreation of primary contact such as swimming, irrigation of vegetables, fruit trees of parks, gardens and aquaculture or fishing activities), that is, they refer to water bodies (BRASIL, 2005). The water quality conditions for Class 2 are the same as those of Class 1 with the exception of BOD (<5 mg L⁻¹), DO (> 5 mg L⁻¹) color (<75 mg Pt L⁻¹) as well as fecal and total coliforms (<1000 and 5000 MPN in 100 mL).

Results and discussion

Evaluation of water contamination at Sanga Lagoão

The sampling point AR1 is the first point of the watercourse on the map (Figure 1), and it only influences the agronomic research activities located in areas of higher elevation. However, when pluviometric precipitation occurs, this site can receive water from other sites, such as the Botanical Garden and the Cohab Fernando Ferrari, thereby increasing the potential for water contamination. However, it should be noted that the harvesting was carried out in a period with low frequency of agricultural activity, at the end of the summer harvest and at the beginning of the off-season.

The temperature values found in point AR1 were 22.3°C and 12.1°C in the first and second samplings, respectively. The temperature is a determinant factor in the targeting of reactions that affect physical, chemical and biological processes and is linked to DO saturation and the rates of biological and chemical reactions in the aquatic environment (Jordão and Pessôa, 2011). Regarding the parameters pH, DO, EC and turbidity (Figure 3), values which satisfy the current quality standards for class 2 waters were presented. Federal law states that for Class 2 waters, the DO concentration in any sample may not be less than 5 mg L⁻¹ of O₂. The DO is essential for aerobic organisms, since during the stabilization of organic matter, bacteria make use of oxygen in their respiratory processes, which can lead to a reduction in the concentration of the same in the environment. From this, DO is the main parameter

used to characterize the effects of water pollution by organic materials (Von Sperling, 2005).

The values obtained at the point AR1 in the two samplings for the total and fecal coliforms, TOC, TN and COD were also within acceptable limits (Figure 4). According to the CONAMA Resolution 357/2005, the maximum values of thermotolerant coliforms in Class 2 water bodies should not exceed 1000 MPN.100 mL. For AR1 the values are within the limits allowed by thermotolerant coliforms, a group of which *Escherichia coli* is part (values less than 11 MPN.100 mL).

The TOC parameter is an indicator of the concentration of organic matter present in water bodies, divided into dissolved or particulate fractions. The continued deposition of hazardous organic substances affects biodiversity and the functioning of aquatic ecosystems (Gosset et al., 2016). In surface waters, the concentration of TOC varies between 1 and 20 mg L⁻¹, increasing up to 1000 mg L⁻¹ in the wastewater, significant changes in this parameter are indicative of new sources of pollution (Libânio, 2010). High concentrations of TN originate from domestic and industrial dumps, animal excrement, fertilizers and biological compounds (Libânio, 2010). N is indispensable to algal growth, but its excess causes eutrophication. The AR1 point presented TOC values according to the range established by the author (12.39 mg L⁻¹ and 11.97 mg L⁻¹, in the first and second samplings, respectively). For NT, the legislation does not establish limits of quality, but it has been verified that the values found are relatively low.

Figure 3. Results obtained for analysis of pH, DO, EC and turbidity.

As for the P content, the total value allowed by the CONAMA Resolution 357/2005 is up to 0.1 mg L⁻¹ for water bodies. At this point, values ranged from 0.22 to 0.29 mg L⁻¹, at the second and first samplings, respectively. Possibly, these high levels of P are from fertilizer residues used in agricultural crops of the experimental areas around the point, or even from the decomposition of organic matter. This explains the temporal variation in P concentration, according to the bed flow and management of the agricultural area. If phosphate accumulation occurs in the water column, there will be an increase in algal blooms and phytoplankton, thereby resulting in eutrophication.

The BOD indirectly shows the organic matter content in sewage or water bodies, thus being an indication of the potential of DO

consumption. Thus, it constitutes a parameter of fundamental importance in the characterization of the degree of pollution of the water body (Von Sperling, 2005). The concentrations of BOD5 determined in the first and second samples were respectively 13 and 2.2 mg L⁻¹. This demonstrates a temporal variation in water quality parameters of the water body, and would characterize the first sampling as contaminated, since the values allowed by CONAMA Resolution 357/2005 for BOD5 at 20°C are up to 5 mg L⁻¹. Therefore, monitoring of water quality is very difficult to perform because of the uncertainties inherent in the sources of contaminants and the complex interconnectivity between water quality parameters and attributes related to the river, such as land use distribution, as well as organic and aquatic plants (Kim et al., 2017).

Figure 2. Results obtained for analysis of total and fecal coliforms, TOC, TN, total P, BOD and COD.

One of the advantages of measuring COD over BOD is that it considers the demand for biologically satisfied oxygen as well as everything that is susceptible to oxygen demand, such as oxidizable minerals (Jordão and Pessôa, 2011). The legislation does not establish concentration limits for COD, but water bodies with high COD content may present oxygen deficits to aquatic organisms. In the stream, mean concentrations of 137 and 183 mg L⁻¹ were found in the AR1 point, in the first and second samplings, respectively.

Table 1 shows the concentrations of total metals found in the two samplings performed and the standards established by CONAMA Resolution 357/2005 for class 2 waters. It should be noted that the federal legislation has not established water quality limits for all the evaluated metals, and the Ni and Cd metals were undetected. The AR1 point did not exceed the contents in any total metal. Table 2 shows the concentrations of dissolved metals found in the two samples collected. The CONAMA Resolution 357/2005 established limits only for dissolved Al (0.1 mg L⁻¹), dissolved Cu (0.009 mg L⁻¹) and dissolved Fe (0.3 mg L⁻¹), as regards quality standards for class 2 waters. The Al and Fe contents were found to be above the limit allowed by the CONAMA Resolution 357/2005, and the Al levels are twice the acceptable limits (0.2 mg L⁻¹ of Al in sampling 2) and Fe (0.7 mg L⁻¹ of Fe in sampling 1).

The second sampling point in the stream, AR2 (Figure 1) is located at the junction of wastewater from buildings 17, 18, 19, 20 and 21 to the north, and 40, 42, 43 and 44 to the south, and following the sanga after AR1. This point is reached by agronomic activities on a smaller scale, as well as by waters used for academic purposes, both in the scope of teaching and research. This point, as well as AR1, also presented values of pH, DO, EC and turbidity within those required by the legislation (Figure 3). The values of total and fecal coliforms, TOC, P, TN, COD and BOD, presented a similar behavior to the AR1 point, showing the total P contents of 0.37 and 0.28 mg L⁻¹, in the first and second samplings, respectively. These values, above the permitted reference values (0.1 mg L⁻¹), possibly occurred as a result of the practices in the surrounding buildings, which flow to the sampling point, as well as some effects of the agricultural practices monitored in AR1. Another parameter which exceeded the permitted limits was the BOD5 for the second sampling, presenting 11 mg L⁻¹, which is more than double the allowed limit (5 mg L⁻¹), demonstrating the variation in time scale.

Regarding the total metals (Table 1) which have a maximum permitted value (MPV), all met the criteria established by the legislation, with the exception of Ag, which presented a concentration of 0.2 mg L⁻¹ in the first sampling, which is above the concentration by legislation (0.01 mg L⁻¹). For the dissolved metals (Table 2), the concentrations of Al exceeded the limits allowed in the two samplings, with contents of 0.2 mg L⁻¹ in both.

Thus, it can be stated that water from the stream leaves the agricultural area already with high levels of dissolved P, Al and Fe as well as BOD values above the permitted limits. Only the total content of Ag was increased in the passage of water by the buildings, since there is a system for the capture and storage of wastewater.

Point AD1 is in the university restaurant discharge area and some CEU II buildings, thus it receives waste from a variety of sources, from large-scale food chain sources such as those commonly used by dwellers. This effluent, before being disposed into the soil, receives treatment in a septic tank followed by the use of an anaerobic filter. The results of the determinations of pH, DO, EC and turbidity can be visualized in Figure 3. It can be seen that the pH values are higher (as in AD2, EF1 and EF2) than at the points of the stream, which may be associated with the proliferation of vegetables in general, since with the increase of photosynthesis there is consumption of carbon dioxide, decrease in the carbonic acid of the water and consequent increase of the pH. Low pH values (acid medium) come mainly from the presence of CO₂, mineral acids and hydrolyzed salts (Von Sperling, 2005).

Table 1. Total metal concentrations obtained and guiding values of total metals for water and effluents quality.

Metals (mg L ⁻¹)	MPV (mg L ⁻¹)		AR1		AR2		EF1		EF2		AD1		AD2	
	Water	Effluent	1	2	1	2	1	2	1	2	1	2	1	2
Ca	-	-	7.6	7.2	9.1	7.7	40.4	23.7	54.8	55.3	25.0	15.1	58.1	35.2
Al	-	-	0.5	0.5	0.7	0.7	0.6	0.7	0.2	0.2	0.4	0.5	0.4	0.6
Ba	0.7	5.0	0.1	0.1	0.1	0.1	0.2	0.1	0.09	0.1	0.08	0.06	0.1	0.09
Mg	-	-	4.4	4.3	4.7	4.1	22.4	13.8	16.6	16.9	13.1	9.5	21.5	15.6
La	-	-	0.003	0.003	0.003	nd	0.005	0.003	0.003	0.003	nd	0.003	0.003	0.003
Li	2.5	-	0.06	0.06	0.06	0.06	0.07	0.06	0.08	0.08	0.07	0.08	0.06	0.07
Mn	0.1	-	0.04	0.02	0.05	0.02	0.6	0.3	0.5	0.5	0.1	0.1	0.2	0.3
Sr	-	-	0.1	0.1	0.1	0.1	0.3	0.2	0.3	0.3	0.2	0.2	0.3	0.2
Zn	0.18	5.0	0.06	0.09	0.02	0.03	0.3	0.1	0.02	0.06	0.07	0.2	0.04	0.1
As	0.01	0.5	nd	nd	nd	0.01	nd	0.07	nd	0.02	nd	0.02	nd	0.007
K	-	-	3.9	8.4	4.4	3.4	54.5	30.0	39.9	42.2	97.5	70.3	22.6	46.4
Ti	-	-	0.2	0.3	0.1	0.4	0.2	0.1	0.04	0.2	0.1	0.2	0.02	0.08
Pb	0.01	0.5	0.01	0.007	0.01	nd	0.02	0.01	0.01	0.007	0.04	0.007	0.01	nd
Se	0.01	0.3	nd	0.01	nd	0.01	0.02	0.1	nd	0.05	nd	0.05	nd	0.02
Cu	-	-	0.01	0.05	0.005	0.003	0.1	0.02	0.007	0.01	0.03	0.03	0.03	0.01
Cr	0.05	-	nd	nd	nd	nd	0.01	nd	nd	nd	0.003	0.01	nd	nd
Fe	-	-	1.8	1.2	1.9	1.0	4.8	1.2	0.5	0.3	1.1	0.6	1.6	2.5
Ag	0.01	0.1	nd	nd	0.2	nd	nd	nd	1.2	nd	nd	0.06	nd	nd
B	0.5	5.0	0.04	0.05	0.02	0.04	0.1	0.1	0.09	0.1	0.4	0.13	0.06	0.09
Be	0.04	-	nd	nd	0.003	nd	0.003	nd	0.007	nd	0.003	nd	0.003	nd
Co	0.05	-	nd	nd	nd	0.003	nd	nd	nd	nd	nd	nd	nd	0.003
Mo	-	-	0.003	0.01	0.007	nd	0.005	0.005	nd	0.01	0.007	0.02	0.005	nd
Sb	0.005	-	nd	nd	nd	nd	0.02	0.01	0.01	0.005	0.01	nd	0.007	nd
Si	-	-	1.1	0.6	0.9	0.7	5.9	6.6	6.1	6.7	5.6	6.7	3.1	5.5
Tl	-	-	0.01	nd	0.01	nd	nd	0.04	nd	nd	nd	nd	nd	nd
V	0.1	-	0.02	0.01	0.03	nd	0.04	0.003	0.02	0.003	0.02	nd	0.02	nd

*nd: not detected.

Table 2. Concentrations of dissolved metals obtained at the evaluated points.

Metals (mg L ⁻¹)	AR1		AR2		EF1		EF2		AD1		AD2	
	1	2	1	2	1	2	1	2	1	2	1	2
Ca	1.2	1.5	1.5	1.2	11.9	5.3	8.8	9.0	5.4	3.3	9.3	6.5
Al	0.1	0.2	0.2	0.2	0.03	0.02	0.02	0.02	0.002	0.002	0.007	0.08
Ba	0.04	0.03	0.04	0.02	0.08	0.04	0.02	0.02	0.03	0.02	0.04	0.03
Mg	0.8	0.7	0.9	0.6	4.6	2.4	2.6	2.6	2.4	1.6	3.3	2.5
La	0.001	nd	0.001	nd	0.002	0.001	0.001	0.001	nd	0.001	0.001	0.001
Li	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02
Mn	0.02	0.006	0.02	0.007	0.2	0.09	0.1	0.1	0.03	0.04	0.05	0.06
Sr	0.02	0.02	0.02	0.02	0.08	0.04	0.06	0.06	0.05	0.04	0.06	0.05
Zn	0.02	0.03	0.008	0.01	0.005	0.005	0.009	0.003	0.03	0.009	0.006	0.01
K	0.7	0.5	0.8	0.5	7.4	7.8	5.1	0.5	13.5	8.8	3.1	6.3
Ti	0.05	0.02	0.05	0.02	0.004	0.003	0.02	0.009	0.04	0.003	0.009	nd
Pb	0.001	0.003	0.001	nd	0.01	0.001	0.004	0.002	0.02	0.002	0.003	nd
Se	nd	0.006	nd	0.003	nd	0.005	nd	nd	nd	0.003	nd	0.002
Cu	nd	0.001	nd	nd	0.04	0.004	0.003	0.003	0.008	0.009	0.002	0.003
Cr	nd	nd	nd	nd	0.006	nd	nd	nd	0.001	nd	nd	nd
Fe	0.7	0.3	0.4	0.4	0.1	0.2	0.1	0.1	0.3	0.2	0.07	0.3
B	nd	0.01	nd	0.009	0.01	0.02	0.01	0.02	0.08	0.02	0.004	0.02
Be	nd	nd	0.001	nd	0.001	nd	0.003	nd	0.001	nd	0.001	nd
Co	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.001
Mo	nd	0.002	nd	nd	nd	0.002	nd	0.002	nd	0.002	nd	nd
Sb	nd	nd	nd	nd	0.003	nd	0.002	0.001	0.001	nd	0.002	nd
Si	0.2	0.05	0.3	0.08	1.3	1.0	0.809	0.9	0.8	1.1	0.4	0.8
Tl	0.003	nd	0.003	nd	nd	nd	nd	nd	nd	nd	nd	nd
V	0.009	0.004	0.01	nd	0.02	0.001	0.009	nd	0.007	nd	0.01	nd

*nd: not detected.

Although the law has not specified the minimum values of DO in effluents, in both samplings the value found was 4 mg L⁻¹ of O₂, which is low, since DO is the main parameter for characterizing the effects of water pollution by organic waste (Von Sperling, 2005). Also, the legislation has not established maximum or minimum values for the EC, but in natural waters this parameter ranges from 10 to 100 µS cm⁻¹. However, at the AD1 point, the values of the first and second samples, 1109 and 1144 µS cm⁻¹, respectively, are well above normal values, demonstrating that in waste water, the EC ends up exceeding 1000 µS cm⁻¹. This variable can be used to establish a pollution zone around the effluent (Libânio, 2010). For turbidity, the values presented were less than 100 NTU (Nephelometric Turbidity Unit), but equivalent to the values found in the effluent before treatment (point EF1). This is disturbing because high levels of turbidity can reduce the photosynthesis of submerged rooted vegetation and algae, and consequently suppress fish production and the development of benthic organisms, thus affecting aquatic biological communities (Baldissera et al., 2011).

Bacteria from the coliform group normally inhabit the intestinal tract of warm-blooded animals, thus serving as indicators of the contamination of water samples by domestic effluents (Libânio, 2010). The presence of microorganisms from the total coliform group is indicative of human pollution in the water body. However, its presence in the middle, according to Jordão and Pessôa (2011), does not necessarily characterize human contribution to pollution, since this group of microorganisms can develop in several environments, such as the soil and vegetation and is not essentially associated with human fecal matter, but may be associated with animal fecal matter. In addition, according to Araújo et al. (2015), the processes of survival, retention and transport of microorganisms depend on several factors such as temperature, rainfall, soil type and soil moisture content.

E. coli can be determined by the substitution of thermotolerant coliform parameters according to the limits established by a competent environmental agency. For domestic effluents the limit of thermotolerant coliforms is 10⁶, that is, point AD1 in both the first and second samplings presented values within those permitted by the legislation. Fecal indicator bacteria such as *E. coli* can be used as indicators of pathogens that cause human disease. They occur naturally in the intestinal tract of warm-blooded vertebrates, so

their occurrence in surface water, sewage, soil, and sediment is associated with fecal deposition (Bradshaw et al., 2016; Partyka et al., 2017).

The legislation does not establish limit values for total P and / or TOC for the discharge of effluents; however, the values found are high, reaching 30.4 mg L⁻¹ for P and 271 mg L⁻¹ TOC, emphasizing the great organic load present in this effluent and the contamination of this site. The CONSEMA Resolution, No. 128/2006, provides that the value of BOD5 for liquid effluents from polluting sources other than domestic liquid effluents discharged into water bodies with a flow rate (Q) of less than 20 m³ d⁻¹ is 180 mg O₂ L⁻¹. For sanitary effluents, the maximum concentration indicated is 600 mg O₂ L⁻¹ (Von Sperling, 2005). Based on the concentrations of BOD5 found, it was observed that the AD1 (408 and 248 mg O₂ L⁻¹, in the first and second samplings, respectively) presents sanitary sewage characteristics (mainly in sampling 1), even with higher BOD concentrations to the gross effluent from the EF1 point (302 and 228 mg O₂ L⁻¹). These results indicate that the effluents released in the degraded area are not exclusively sanitary, this was also verified by Araújo et al. (2015). Regarding COD, the average concentration found was higher than 1000 mg L⁻¹ in the first sampling, also higher than the gross effluent. These results, as well as those of BOD5, also emphasize that effluents discharged into the degraded area are not exclusively sanitary and that wastes may occur in this area and that it does not pass through the primary treatment system or is not efficient.

Tables 1 and 2 show the concentrations of total metals and dissolved metals found in the two samplings (1 and 2) and the standards in CONAMA Resolution 430/2011, for effluent discharge. The federal legislation is yet to establish effluent release standards for all metals evaluated in the study. For dissolved metals, limits have been established for dissolved Cu (1.0 mg L⁻¹), dissolved Fe (15 mg L⁻¹) and dissolved Mn (1.0 mg L⁻¹), as regards the quality standards for effluent discharge. Federal legislation was chosen because it establishes conditions and standards for the discharge of effluents for any polluting source. Ni and Cd metals were undetected and all metals having standards met the limits established by the legislation. In the aquatic system, there was toxicity of heavy metals such as Cd, Cr, Ni, Pb and, to a lesser degree, Cu and Zn. According to Andreoli (2006), domestic sewage has small concentrations of heavy metals, such as Ag, As, Cd, Co, Cr, Cu, mercury (Hg), Ni, Pb, Se and Zn.

These elements can be found naturally in soils, plants and animals, but must meet the limits that do not endanger human health and the environment.

The monitored AD2 point may receive untreated sewage dump, since it has a characteristic odor, but it also exists the rainwater drainage system. The point AD2, together with point AD1, are parts of an area where the final discharge of the liquid effluents occurs, directly on the surface of the soil, flowing through zones of preferential flow until reaching Sanga Lagoão do Ouro. At this point, the samplings presented an interesting temporal variation, since in all analyzed parameters the second sampling presented more expressive values, in comparison with the first one, thus demonstrating the potential of soil contamination by the successive addition of untreated effluents.

The DO values of 3 mg L⁻¹ of O₂ in the first sampling diminished to 0 mg L⁻¹ of O₂ in the second, equating to the crude effluent (EF1). On the day that the second sampling was conducted, the effluent from AD2 was very strong and had a greasy consistency, conspicuously with a higher concentration of organic materials when compared to the first sampling, reflecting the absence of DO, increased EC and turbidity. For EC values (593 and 957 µS cm⁻¹) there was a 38% increase in the second sampling as compared to the first one. The BOD contents increased by 51.93% in the second sampling (from 87 mg O₂ L⁻¹ to 181 mg O₂ L⁻¹), which is another indication of the high organic load being released at this point in the days prior to sampling.

In the degraded area, where the points AD1 and AD2 are located, not only was sewage directly discharged into the soil, but residues from different origins were also discarded at the site, such as construction waste, electronics, furniture and recyclable materials as well as plastics and electronics. The soil and the landscape itself are extremely altered at the site and, taking into account that the effluents reach Sanga Lagoão do Ouro, it served as evidence of the great potential of contamination of water resources, both in the surface and subsurface. Several pipelines called point effluent discharge sources have already been identified on the UFSM Campus. In his research, D'Ávila (2009) identified forty-nine pipes of liquid effluent emission. Reckziegel (2012), in his last sampling campaign, found another point source located behind a car garage of UFSM employees, where there is also space for the storage of various tools and materials. According to Araújo (2013), this source is composed of two pipes of 100.0 mm in diameter disposed in parallel, which discharge

effluents 50.0 m from the probable point of origin (building 36, Student House).

The arrival of contaminants in high concentrations in the watercourses represents a high level of contamination, considering the path covered by these contaminants. When analyzing and comparing the water quality of the Sanga Lagoão do Ouro at the entrance and exit of the UFSM Campus with the federal water resources legislation, D'Ávila (2009) found that the quality remained outside the established standards. The values found by the author decreased along the water course, as a result of self-purification, but a good part of these contaminants can infiltrate the environment, since the local lithology, the Formation of Santa Maria is highly vulnerable to the contamination. After eight years of conducting this study, effluent and other wastes (such as detergents, which can be seen at the entrance to the campus) were continuously discharged into the stream water and directly into the ground, as the academic community and the area built by UFSM also increased. Thus, according to Araújo et al. (2015), the discharge of wastewater in this area is inadequate, since it is a highly vulnerable area, the stream already arrives polluted to the Campus and its capacity of self-purification is exhausted.

Efficiency of VFCW of ETE

The effluent pH values of the EF1 (gross effluent) and EF2 (treated effluent) effluents remained within the quality standards required by the legislation (Figure 3). Regarding the concentration of DO for effluent samples, the legislation is yet to establish values. However, it was observed that in the crude effluent (EF1) the concentration of DO found was equal to 0 mg L⁻¹ of O₂, both in the first and in the second samplings, with a slight increase after ETE treatment (6.0 and 6.2 mg L⁻¹ of O₂, in the first and second samplings, respectively). Turbidity values above the permitted limits were derived from particles of rocks, clay, silt, as well as domestic and industrial wastes and erosion. For effluent samples, the legislation does not establish maximum permitted values and, in points AD1 and AD2, the samples of points EF1 and EF2 also did not exceed the limit of 100 NTU. Regarding the efficiency of VFCW, it was efficient in reducing turbidity, thereby reducing the values in the first sampling by 67% (from 65.5 NTU in EF1 to 22.0 NTU in EF2) and in 76.2% in the second (from 85.3 NTU in EF1 to 20.3 NTU in EF2).

It was shown that EC is high in the two ETE points, mainly in the raw effluent (949 and

1074 $\mu\text{S cm}^{-1}$ in the first and second samplings, respectively), but the VFCW was not very efficient in the reduction of salts, and consequent reduction of the EC. Araújo et al. (2015) observed a reduction in mean EC values in two wells located in the degraded area, as they differed from effluent release sources. Thus, as the effluent flows through the substrate, the anions and cations present in the effluent bind to other compounds, thereby reducing the transmission of electric current.

VFCW is also effective in the removal of pathogens, since it was efficient in the removal of total coliforms (efficiency of 61.02% in the first sampling and 87.42% in the second sampling) and relatively efficient in the removal of *E. coli* (24.55% in the first sampling and 35.94% in the second sampling). This was due to the fact that the plants already have a properly developed root system, which plays an important role in the retention of pathogenic organisms in these systems. For total P, a good removal efficiency was not obtained, since it was 20.96% in the first sampling and only 16.57% in the second sampling. According to Stefanakis and Tsihrintzis (2012), the low removal of P from the VFCWs may be related to the low contact time of the wastewater with the filter material, and the removal efficiency of P in these systems is generally low at the beginning of the operation.

Regarding the efficiency of TOC removal, the VFCW was relatively efficient in reduction, decreasing by 54.54% and 58.28% the contents in the first and second samplings, respectively. For TN, the VFCW reduced by 20.04% and 32.06% the contents in the first and second samplings, respectively. The percentage of TOC and TN removal was not as high as the assimilation of nutrients in larger quantities which occurs at the beginning of the development of plants, where the cells require a large amount of proteins and nucleic acids (Liu et al., 2011). However, the VFCW showed very efficient removal of BOD₅, when it presented efficiency of 84.77% and 85.53%, in the first and second samplings, respectively and in the removal of COD, presenting efficiency of 81.87% in the first sampling and 81.75% in the second sampling. The experimental system met the concentrations of BOD and COD in the final effluent in accordance with the standards established by resolutions of CONAMA No. 430/2011 and CONSEMA No. 128/2006. The first established a standard of 120 mg L^{-1} for BOD or a minimum of 60%. The second one established that domestic effluents can only be released in Rio Grande do Sul water bodies respecting the

standards of 180 mg L^{-1} for BOD and 400 mg L^{-1} for COD (in the flow range $<20 \text{ m}^3\text{d}^{-1}$).

As for metals, the first point was the EF2 point, that is, the effluent treated by the VFCW presented a higher concentration of Ag (1.2 mg L^{-1}) compared to the established value (0.1 mg L^{-1}). Generally, Ag occurs in natural waters at low concentrations, between 0 and 2 $\mu\text{g L}^{-1}$, since many of its salts are poorly soluble. Considering the Resolution of CONSEMA 128/2006, the concentration of Ag detected would not meet the standards for the effluent. The VFCW was efficient in removing Cu (95.33% and 60.0% removal efficiency in the first and second samplings, respectively), Zn (91.21% and 34.31% in the first and second samplings, respectively) and total Fe (88.74% and 72.93% in the first and second samplings, respectively). Plants serve as a substrate for various microorganisms that participate in the degradation of organic matter and assist in the removal of nutrients and heavy metals. These microorganisms which adhere to the roots of plants and to the gravel in VFCW are responsible for the purification of sewage.

The treatment of liquid effluents is the responsibility of the public, and the population in general can play a much larger role in order to mitigate the problem. Future research should focus on the development of participatory approaches, with the planning and optimization of water quality monitoring programs (Behmel et al., 2016). One of the actions in this direction and, following the work developed in the VFCW, would be the installation, in urban condominiums and other housing settlements, including in rural areas, of decentralized stations, in which domestic sewage is treated through natural processes. Groundwater effluent disposal sites on the UFSM Campus deserve special attention due to the possibility of proliferation of organisms harmful to health and the high potential for groundwater contamination. Monitoring water quality is essential for determining the impacts of human activities, the suitability of water for human use, as well as sediment and contaminant flows to water bodies (Chapman et al., 2016).

Conclusions

The AR1 and AR2 points located in the stream had concentrations of total P (first and second samplings) and BOD (first sampling) above the permitted limits. Among the total metals that have MPV, all met the criteria established by law, with the exception of Ag in

points AR2 and EF2 (first sampling). At points in the stream, AR1 and AR2, the dissolved Al and Fe contents were above the limit allowed. The points AD1 and AD2 located in the degraded area by the effluent discharge presented characteristics of raw effluent, mainly in the second sampling, such as the absence of DO as well as high BOD and COD values, even at concentrations higher than those at point EF1. It is inferred, therefore, that in this area the effluent released is not exclusively sanitary and that waste disposal (from the RU or other sources) does not undergo the primary treatment system.

VFCW proved to be efficient in reducing turbidity, BOD, COD as well as the total metals Cu, Zn and Fe and was relatively efficient in the removal of TOC. However, the reduction of TN, total P and EC by the VFCW was inefficient.

Existing watercourses within the UFSM campus are highly vulnerable to contamination and are degraded due to the inadequate release of effluents generated primarily in the CEU-II and the RU. Mitigating actions such as the installation of decentralized effluent treatment plants in urban condominiums and rural areas are fundamental practices for the sustainability of water resources and for the protection of human and animal health.

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