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BIOTECHNOLOGY

Efficiency of the treatment system of wastewater at a kennel

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ABSTRACT. Abandoned canine on streets have been an increasing issue in the majority of Brazilian cities. In order to decrease this problem, many countries have created kennels, which are unities reserved to shelter dogs. The animal confinements produce a huge amount of solid and liquid waste in concentrated residues. There are only few studies about those residues. The kennel Parque Francisco de Assis, located in the municipality of Lavras, shelter about 400 dogs and it has an individual system of treatment, composed by grating and decanter, septic tanks with anaerobic filters (ST-ANF), and stabilization tanks for treatment of wastewater produced in the activity. The aim of this study was to evaluate the system of wastewater treatment of the kennel by the qualitative characterization through physical, chemical and biological analysis of the influent and effluent from the unities that are in the treatment system, thus obtaining the efficiency of the process. The average efficiency of the removal in the treatment system was approximately 65% of organic matter, 11% of nutrients and 59% of coliforms; therefore, it was featured as unsatisfactory to release according to the normative deliberation Copam/Cerh nº 01/2008, altering the conditions and standards of the stream in a negative way.

Keywords: dogs; biological treatment; septic tank-anaerobic filter system; pollution.

Eficiência do sistema de tratamento de efluentes de canil

RESUMO. Cães abandonados nas ruas têm se tornado um problema crescente na maioria das cidades brasileiras. Para amenizar o problema, muitos municípios têm criado os canis, unidades destinadas ao abrigo dos cães. O confinamento dos animais proporciona a geração de grande quantidade de resíduos sólidos e líquidos de forma concentrada. Tais resíduos são ainda pouco estudados. O canil parque Francisco de Assis, Lavras-MG abriga cerca de 400 cães e possui um sistema de tratamento individual, composto por grades e decantador, tanques sépticos seguidos de filtros anaeróbios (TS-FAN), e tanques de estabilização para tratamento das águas residuárias geradas na atividade. O objetivo deste trabalho foi avaliar o sistema de tratamento das águas residuárias do canil a partir da caracterização qualitativa, por meio de análises físicas, químicas e biológicas, do afluente e do efluente das unidades que compõem o sistema de tratamento, obtendo-se a eficiência do processo. A eficiência média de remoção no sistema de tratamento foi aproximadamente de 65% de matéria orgânica, 11% de nutrientes e 59% de coliformes, caracterizando-se como insatisfatórias, para os padrões de lançamento conforme deliberação normativa Copam/Cerh nº 01/2008, alterando as condições e padrões do ribeirão de forma negativa.

Palavras-chave: cães; tratamento biológico; sistema tanque séptico-filtro anaeróbio; poluição.

Introduction

Every shelter or place designated to house and assist dogs create animal sewage from sanitation of stalls. This sewage has features that indicate its polluter potential, which is only inferior of human sewage. Consequently, the sewage may just be released directly in water body after proper treatment, which must follow the conditions, standards and requirements from the applicable regulation (Brasil, 2011). Otherwise, there will be risks to soil, hydric resources and to public health.

However, kennels that shelter a large population of canine, besides generating considerable volume of effluents, are usually located far from cities or in rural areas, which do not have public sewage collection treatment system. That reality corroborates to the need to develop, on the local of the kennel, economically viable technologies for an individual effluent treatment system.

The kennels play an important role on sanitary and public health function. Several Brazilian counties search for an installation of those shelters to control the canine population, since abandoned animals, without proper care, are host to more than 300 types of zoonosis, mainly rabies and leishmaniasis (Garde, Acosta-Jamett, & Bronsvoort, 2013).

Thus, the relevance of maintaining the social activities of the kennels provides the achievement of a simplified individual treatment of the generated effluent, since more than an aspect of environmental protection, the sewage treatment is also a public health matter.

Generally, the simplified and individual system has received less attention, and with the improper discharge, it has caused severe environmental impacts. It is mainly due to a lack of control, because despite of the simplicity of systems, there is the demand of certain monitoring which, in the majority of cases, it does not happen, due to lack of knowledge about the effluent, operation and performance of the system. This fact is aggravated by the current precarious situation of sanitation in Brazil, primarily in rural areas.

Therefore, the current study contributes to the information of the kennel effluent and the simplified and individual treatment by septic tank followed by anaerobic filter (ST-ANF), by means of effluent monitoring in the treatment, in order to evaluate the performance and the efficiency of the system, for knowledge of the necessary corrective measures, aiming at meeting the standards of effluent release in watercourse.

Material and methods

The study was developed at the kennel Parque Francisco de Assis (PFA), in the municipality of Lavras, Minas Gerais state. The PFA exist to shelter abandoned, sick and mistreated dogs that live on streets, which will be sent to adoption after receiving proper treatment.

The liquid and solid manure from about 400 dogs, which live within an area of 7000 m^2, are separated by stalls scraping before washing. At the kennel, the solid part is treated by composting and the liquid part, which consists basically in water from the daily washing of the stalls, is treated in a simplified system of treatment. The effluent is produced between 9 a.m and 4 p.m, daily, during the stalls washing.

The current treatment system of the effluents from animals begins with a pre-treatment by firstly grating the sewage in a 4 m^3 decanter, which receives the greatest part from the effluent to be treated. Then, the wastewater is forwarded to an primary/secondary unit of treatment composed by a septic tank followed by anaerobic filter of ascendant flow with 10 m^3 each, the filter has support material type stone gravel n° 4. The other part is composed by less amount of wastewater, and it is forwarded to another grating and primary/secondary unit of treatment composed by a septic tank followed by anaerobic filter of ascendant flow with 5 m^3 each with the same setting. The effluents from both anaerobic unities are directed to a group of 10 fiberglass tanks with capacity of 1 m^3 each, with tabulation of entrance and exit at half height from the tanks, which will function as complementary and facultative treatment unities to stabilize the organic matter.

After the treatment, the effluent is released in the river Santa Cruz. Figure 1 presents a schematic diagram of the treatment system of the kennel.

1- Sample composed from raw effluent after grating;

2- After the anaerobic treatment of the two unities of anaerobic septic tank;

3- After the last tank of stabilization, before the release at the stream (Figure 1).

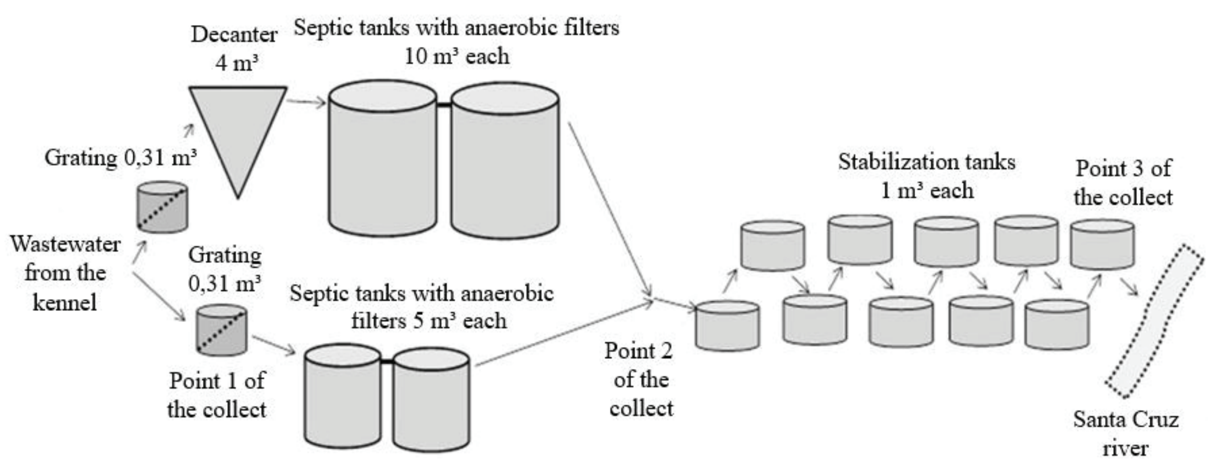

Figure 1. Schematic diagram of the system treatment of wastewater from the kennel PFA.

The collection of the effluent from each point was done in intervals of one hour, during all the time of stall washing, a procedure that was performed every week during fifteen consecutive weeks, totaling fifteen samples of each point, and one hundred and six days of monitoring, adding the consecutive weeks of analyzes. Sampling was made with the same volume every hour, by mixing the contents in a single plastic flask, in order to guarantee a composed, homogeneous and representative sample from the system. The same process was executed in all collection parts.

From the fifteen samples of the effluents from each part, the analyses of the variables was performed, determining the pH using the potentiometric method; biochemical demand of oxygen by titration of the dissolved oxygen, by the Winkler method after 5 days of incubation of the sample in 20°C; biochemical demand of oxygen in closed reflux; total and suspended solid by gravimetry; total phosphor by the method of vanadate-molybdate complex and colorimetric dosage in spectrophotometry; total nitrogen (TKN) by the method of micro-Kjeldahl. For the surfactant (detergent) elements variable, nine samples were analyzed, by colorimetry after extraction with chloroform. For the variables of total and thermotolerant coliforms, six samples were analyzed, by the method of multiples tubes. Regarding the copper and zinc variables, five samples were analyzed, by spectrophotometry of atomic absorption after extraction from acid digestion (American Public Health Association [APHA], American Water Works Association [AWWA], & Water Environment Federation [WEF], 2005).

Based on the results obtained every week, it was calculated the efficacy of each variable, in each unit of treatment and in total, as a system. Thus, with the weekly measures of efficacy, it was possible to evaluate the efficacy of the system related to the legal patterns to release effluents in water bodies.

The system monitoring data were submitted to the Tukey test, for comparison of different means statistically significant between the points and in relation to the standards (reference values) of water inlet/disposal. The test was performed in the statistical analysis program Statistica.

Results and discussion

Table 1 presents the monitoring results, which are composed by the features of the affluent and effluent from the unities that are within the treatment system, the efficacy of treatment unities and the patterns of release, for each parameter evaluated.

Table 1. Monitoring results of the wastewater treatment from the kennel PFA.

Parameters and efficacy	Sample points			E* (%) Total	Standards of releasing**
	1	2	3		
pH	7.2±0.3 b	7.9±0.2 a	7.9±0.1 a	–	6 to 9
p-value 1	–	0.000119	0.000119	–	–
p-value 2	0.000119	–	0.729270	–	–
p-value 3	0.000119	0.729270	–	–	–
Detergent (mg L^{-1})	4.4±1.9 a	3.7±1.6 a	3.5±1.2 a*	–	< 2.0 mg L^{-1}
p-value 1	–	0.672905	0.481965	–	–
p-value 2	0.672905	–	0.947104	–	–
p-value 3	0.481965	0.947104	–	–	–
p-value 3 with standard	–	–	0.001725	–	0.001725
E (%)	–	14	11	17	–
BOD (mg L^{-1})	189±53 a	117±36 b	52±16 c	–	< 60 mg L^{-1}
p-value 1	–	0.000134	0.000119	–	–
p-value 2	0.000134	–	0.000195	–	–
p-value 3	0.000119	0.000195	–	–	–
p-value 3 with standard	–	–	0.052605	–	0.052605
E (%)	–	36	52	70	> 75%
COD (mg L^{-1})	612±76 a	334±97 b	239±58 c*	–	<180 mg L^{-1}
p-value 1	–	0.000119	0.000119	–	–
p-value 2	0.000119	–	0.005084	–	–
p-value 3	0.000119	0.000119	–	–	–
p-value 3 with standard	–	–	0.000570	–	0.000570
E (%)	–	44	28	60	> 70%
TS (mg L^{-1})	926±205 a	546±132 b	524±115 b	–	–
p-value 1	–	0.000119	0.000119	–	–
p-value 2	0.000119	–	0.924518	–	–
p-value 3	0.000119	0.924518	–	–	–
E (%)	–	38	7,4	40	–
SS (mg L^{-1})	313±132 a	74±37 b	50±36 b*	–	< 100 mg L^{-1}
p-value 1	–	0.000119	0.000119	–	–
p-value 2	0.000119	–	0.686496	–	–
p-value 3	0.000119	0.686496	–	–	–
p-value 3 with standard	–	–	0.000147	–	0.000147
E (%)	–	74	43	83	–

Parameters and efficacy	Sample points			E* (%) Total	Standards of releasing**
	1	2	3		
TP (mg L^{-1})	165±36 a	136±33 a	145±42 a	–	–
p-value 1	–	0.090755	0.317744	–	–
p-value 2	0.090755	–	0.769716	–	–
p-value 3	0.317744	0.769716	–	–	–
E (%)	–	18.4	–	18	–
TKN (mg L^{-1})	94±37 b	146±53 a	138±52 a*	–	< 20 mg L^{-1}
p-value 1	–	0.013357	0.043048	–	–
p-value 2	0.013357	–	0.882758	–	–
p-value 3	0.043048	0.882758	–	–	–
p-value 3 with standard	–	–	0.000141	–	0.000141
E (%)	–	4	12	3	–
CT (MPN 100 mL^{-1})	$2.34x10^{12}\pm5.71x10^{12}$ a	$1.59x10^{11}\pm3.87x10^{11}$ a	$5.24x10^{10}\pm9.78x10^{10}$ a	–	–
p-value 1	–	0.503920	0.472122	–	–
p-value 2	0.503920	–	0.998354	–	–
p-value 3	0.472122	0.998354	–	–	–
E (%)	–	62 (1 log)	27 (1 log)	48 (2 log)	–
CF (MPN 100 mL^{-1})	$1.84x10^{12}\pm4.49x10^{12}$ a	$1.59x10^{11}\pm3.88x10^{11}$ a	$5.22x10^{10}\pm9.79x10^{10}$ a	–	–
p-value 1	–	0.517206	0.476622	–	–
p-value 2	0.517206	–	0.997300	–	–
p-value 3	0.476622	0.997300	–	–	–
E (%)	–	78 (1 log)	43 (1 log)	63 (2 log)	–
Cu (mg L^{-1})	0.05±0.02 a	0.02±0.01 b	0.02±0.01 b*	–	< 1.0 mg L^{-1}
p-value 1	–	0.013646	0.013106	–	–
p-value 2	0.013646	–	0.999748	–	–
p-value 3	0.013106	0.999748	–	–	–
p-value 3 with standard	–	–	0.000223	–	0.000223
E (%)	–	53	18	55	–
Zn (mg L^{-1})	0.53±0.16 a	0.21±0.02 b	0.17±0.02 b*	–	< 5.0 mg L^{-1}
p-value 1	–	0.000613	0.000322	–	–
p-value 2	0.000613	–	0.770571	–	–
p-value 3	0.000322	0.770571	–	–	–
p-value 3 with standard	–	–	0.000223	–	0.000223
E (%)	–	57	19	65	–

*Efficacy; **Minas Gerais (2008); Averages followed by the same letter do not differ statistically from each other, and averages of point 3 with an asterisk (*) differ statistically with the respective release standards, at the 5% level of significance.

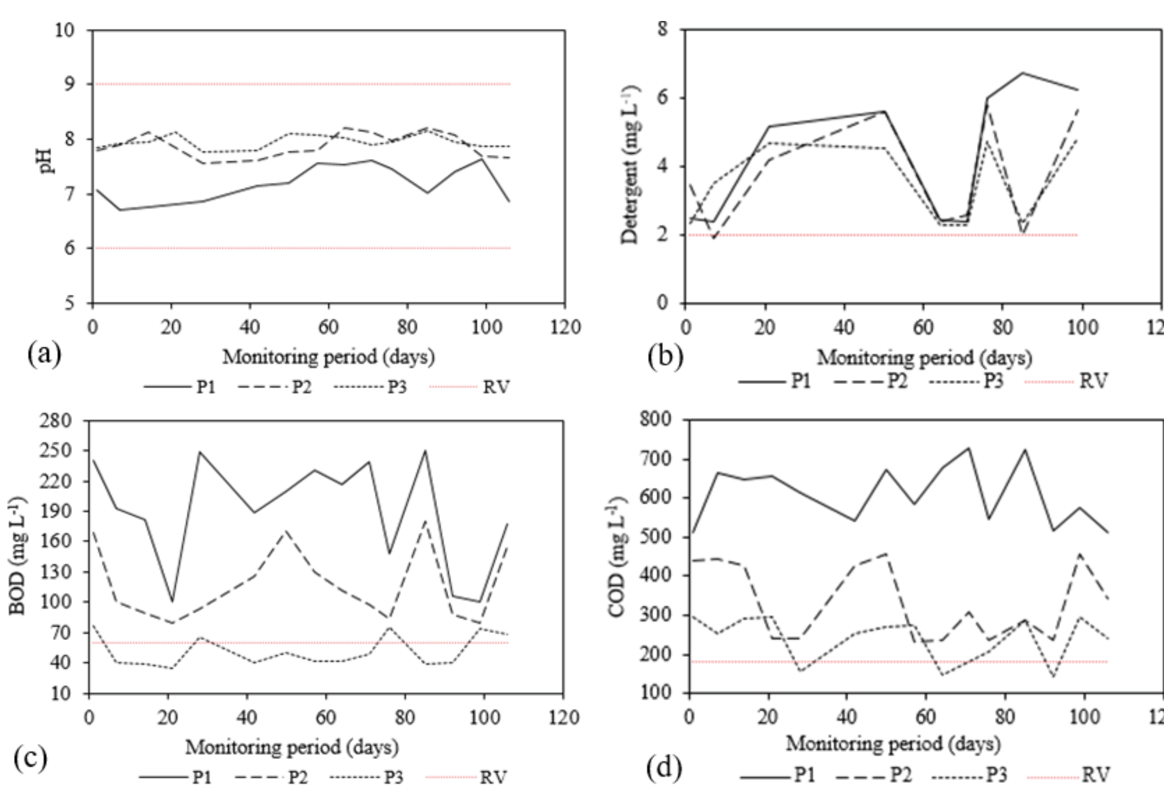

Figure 2. (a) pH, (b) detergent, (c) BOD, (d) COD, (e) TS, (f) SS, (g) TP, (h) TKN, (i) CT, (j) CF, (k) Cu and (l) Zn values of the wastewater from the wash of the PFA kennel dogs and after the different treatment units; and reference values (RV) for disposal in watercourses

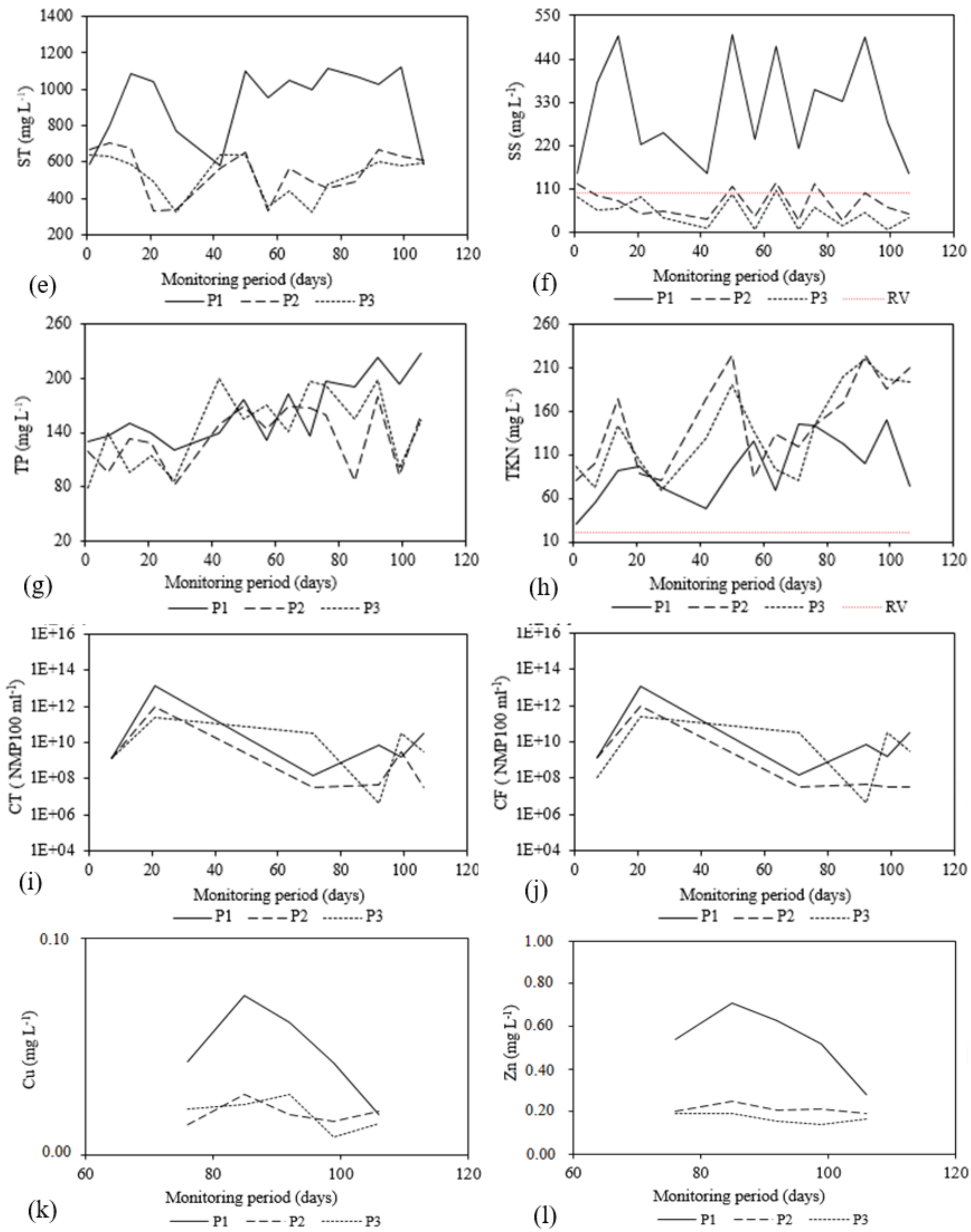

Figure 2 (continuation). (a) pH, (b) detergent, (c) BOD, (d) COD, (e) TS, (f) SS, (g) TP, (h) TKN, (i) CT, (j) CF, (k) Cu and (l) Zn values of the wastewater from the wash of the PFA kennel dogs and after the different treatment units; and reference values (RV) for disposal in watercourses.

Figure 2 shows the variations of the values of each parameter analyzed in the units that make up the treatment system, and the standards (reference values) for launch/disposal in watercourses.

The pH value of the point 1 (Table 1), raw effluent, is similar to the value to the domestic sewage, 7.2, observed by Silva and Souza (2011), and higher than the average of 6.8 of domestic sewage, as found by Lima and Costa (2011). However, it is within the range variation of pH in domestic sewage presented by Von Sperling (2014), ranging from 6.7 – 8.0. According to the author, the typical value is 7.0.

The pH averages found are similar to the monitoring values of domestic sewage treatment in the ST-ANF system, with 7.2 in the raw effluent and 7.3 in the treated effluent found by Silva and Souza (2011). Another similarity to the behavior of the results of these authors is the tendency of a slight increase of pH after the treatment procedures. The pH value of point 1 is smaller and differs statistically from the other points, which present higher values and are equal to each other. According to Chernicharo et al. (2006), the optimum pH range for the development of methanogenic archaea is 6.6 to 7.4, which occurred in the anaerobic treatment units. It can be concluded, therefore, that the system is operating in good conditions, suitable to the reactions of the microorganisms.

The oscillation of the pH values during the monitoring period (Figure 2a) occurred, on average, within the range suitable for the microbial activity responsible for degradation of organic compounds, which is between 6.0 and 8.0. According to Chernicharo et al. (2006), values outside the standard may inhibit the development of microbiota. It was noted stability in the organic treatment, which allows the conclusion that there are not accentuated variations in pH able to compromise the performance of the system. Aiming the release of treated effluent in water body, the pH fully accomplished the minimum and maximum values allowed by the environmental legislation (6 to 9) (Table 1).

The presence of detergent in the wastewater of the kennel is due to the use of cleaning products in the process of stall sanitation. According to Duarte et al. (2008), the main forms of surfactant removal are the biological processes, with efficacy values around 80%, which evidence the low rates of removal in the treatment from PFA (Table 1). The detergent values at the three treatment sites do not differ statistically from each other; therefore, they present the same concentration throughout the treatment.

Reduced efficiency in detergent removal in effluent treatment systems were described by Scott and Jones (2000), who stated that aerobic treatment systems are more efficient in the removal of those substances, when related to anaerobic. Researches about anaerobic degradation have shown that the removal is possible, in the majority of studies using reactors Uasb (Duarte, Oliveira, Buzzini, Adorno, and Varesche, 2006; Oliveira, Duarte, Sakamoto, & Varesche, 2009; Oliveira et al., 2010). According to Ying (2006), the biodegradation of detergents may be influenced by several factors, which depends on molecular structure of surfactant, chemical conditions of the environment, type of microscope, and others.

According to the detergent concentrations found and the low (statistically zero) removal efficiency, the treatment under study did not reach the effluent discharge pattern. The detergent concentration at the end of the treatment (point 3) is statistically different and higher than the reference limit value for water supply (Table 1).

The concentration of BOD in the effluent from PFA was superior to the one of wastewater in a kennel studied in Washington D.C., in the United States. Jaworski and Hickey (1962) verified the average value of BOD from 90 mg L^{-1} and the maximum value 230 mg L^{-1}. In that study, the cleaning process was the same as the one adopted in PFA: rasping procedure of the stalls with posterior washing. However, in the PFA an average of approximately16 L of water per animal per day is spent to maintain the animals and clean the facilities, which increases the organic concentration in the effluent; however, Jaworski and Hickey (1962) verified a daily consumption of 32 L per day for each animal (300 animals) and an effluent more diluted. Furthermore, the concentration of organic matter may be influenced by the size of the dog and the frequency of feeding.

When comparing the results from point 1 (Table 1) with data of domestic sewage, the sewage presents a typical value of BOD equal to 300 mg L^{-1} and a range variation between 250-400 mg L^{-1}, therefore, having an average concentration of BOD more elevated than the one found in this study (189 mg L^{-1}). Regarding the average concentration of COD, the domestic sewage presents value close to that of this study (612 mg L^{-1}). According to Von Sperling (2014), the typical value of COD for domestic sewage is 600 mg L^{-1}, with a range between 450-800 mg L^{-1}. Oliveira and Von Sperling (2005) found superior results, when evaluating 166 wastewater treatment plants, in which the affluent presented average of 527 mg L^{-1} of BOD and 1113 mg L^{-1} of COD. According to the authors, the occurrence of industrial organic contribution may justify the elevated concentrations of BOD in the sewage, a factor that does not exist to the effluent of PFA.

Besides the concentrations of COD and BOD, the relation between them must be highlighted. Whereas in the domestic sewage the typical relation between these factors is equal two, the average relation of the wastewater from the kennel was 3.2. This fact does not impede the biological treatment (Von Sperling, 2014), however, since it indicates that the biodegradable fraction is not elevated, it could impair the treatment, and consequently the removal of organic matter.

Regarding the wastewater from PFA, it is understood that besides biodegradable fraction, there is also a considerable inert fraction, which might be some toxic component or refractory compounds of low biodegradability, and consequently it is recommendable deeper studies about its biological treatment. This inert feature may be attributed to the presence of dog's fur, which is a material of difficult biological degradation (Korniłłowicz-Kowalska & Bohacz, 2011), in addition to the oils and greases that may have inhibited the action of microorganisms (Merrettig-Bruns & Jelen, 2009; Affandi, Suratman, Abdullah, Ahmad, & Zakaria, 2014).

The lower values of BOD and COD can be considered an advantage in relation to the other effluents, since the wastewater of the PFA presents less polluting potential in terms of organic load, compared to the other cited examples. However, its negative impacts by releases without a treatment are the same, and depend on the receiving water body or the dumping site.

The samples from point 2 presented low values with some peaks accompanying the elevation of the organic load affluent to the system (point 1) (Figure 2c and d). However, the efficiency of removal in this point, in other words, after the anaerobic phase of treatment, in the ST-ANF system, was inferior in the BOD parameter and superior in COD parameter. It presented the phase of more efficiency in removal to COD (Table 1), thus confirming the perspective that the system ST-ANF, mainly in the septic tank, presented removal predominantly in physic matter, functioning as decant-digesters and, to an inferior extent, promoted the biological removal of organic matter (Von Sperling, 2014).

The BOD and COD values of the three points differ statistically, showing a significant removal. For BOD the units that promoted the most marked removal were the stabilization tank (point 3), after the optional treatment phase. However, the average of this point is not significantly different from the maximum value allowed by the legislation (60 mg L^{-1}), it is therefore statistically similar, not meeting the standard of releasing (Table 1). In this phase the COD parameter had its efficiency reduced (Table 1), probably due to the fact that it is a predominantly biological treatment, and the high COD/BOD ratio presented by the effluent of the anaerobic units (2.9). Another factor that may have contributed to the lower removal efficiency in general was the sudden flow variation, which causes the drag of solids, composed of organic matter, causing higher COD values at point 3 in relation to point 2 (Figure 2d). There was intense rain in the previous day and during the collection at the monitoring days 21 and 57. With the interference of the amount of the rainwater, the treatment flow was increased, and thus, the time of detention of the effluent in the tanks was reduced, which may have favored an increase in the organic concentration in the wastewater from the treatment exit, since the degradation of organic matter occurs in this step.

Considering that in point 2, after the anaerobic phase, there was no change in the COD concentration in the rainy season, it is understood that the ST-ANF system of the anaerobic phase presented greater capacity to withstand the flow variation, time of detention and variation of the organic load, since the bays taken by rainwater, which was sent to the treatment system, contained animal waste.

The reduction of COD removal efficiency at point 3, presenting a statistically different concentration, which was higher than the release pattern, influenced the low total efficiency value of the treatment system for the variable, equal to 60%, not meeting the minimum of 70% established in the environmental laws. The total efficiency of BOD removal was 70%, which also do not meet the minimum of 75%.

The wastewater treatment plant with facultative lagoon, in an evaluation performed by Oliveira and Von Sperling (2005), also presented greater accomplishment in the removal of organic matter (75% BOD and 55% COD) and greater average efficiency, when related to BOD. Thus, they obtained results closer to the recommendable for release, compared to the stabilization tanks from PFA.

Oliveira and Von Sperling (2005), and Silva and Souza (2011) found higher values for average removal efficiency of organic matter in wastewater treatment plant with ST-ANF system. The values found by these authors were 59% to BOD and of 51 to 55% to COD. These results are below the results found by Moura, Batista, Silva, Feitosa, and Costa (2011), when treating domestic sewage in rural areas in TS- FAN system. In the study of Moura et al. (2011), they found values varying from 66 to

88% to BOD and from 77 to 81% to COD, which are great results, according to the range cited by Von Sperling (2014) for BOD (80-85%) and COD removal
(70-90%) in ST-ANF system.

These results lead to the conclusion that the efficiency of organic matter removal from the treatment system under study was not satisfactory. Even the average value of BOD, at point 3, has met the maximum concentration limit, the statistic shows that it was not significantly enough. Nevertheless, the removal efficiency was low and the COD concentration did not meet the recommended standards. The BOD and COD (Figure 2c and d) must suit the regulation, in order to the treatment system reach the efficiency in organic matter removal.

Considering the solid parameter, Jaworski and Hickey (1962) verified the maximum value of TS of 2360 mg L^{-1}, and the average value of 1050 mg L^{-1} (calculated) in wastewater from a kennel studied in Washington D.C., in the United States. The average value found in their study is close from the one observed in the present research (Table1).

Comparing the data of the PFA effluent with domestic sewage, the average TS of the raw effluent from PFA (point 1) (Table 1) is within the variation range 700-1350 mg L^{-1}, presented by Von Sperling (2014), which demonstrates lower concentration than the typical value (1100 mg L^{-1}). Moura et al. (2011) verified TS concentration below the typical value, equal to 852 mg L^{-1}, also in domestic sewage.

Due to the elevated TS concentration at point 1 (Table 1), with mean statistically different from the other points, it is considerable can be considered that both the anaerobic unities and stabilization tanks were able to cushion the concentrations of solids affluent in treatment. However, the means of points 2 and 3 did not differ statistically from each other, showing that ST removal was more evident to anaerobic unities, which worked more with decantation unities.

In the graphs (Figure 2e and f), most of the affluent solids of the treatment system were composed of dissolved solids (66% of TS). When passing through anaerobic treatment, the concentration of suspended solids was reduced, and the concentration of dissolved solids was proportionally even higher (86% of TS). In the final effluent, after the stabilization tanks, the concentrations of dissolved solids were also proportionally higher (90% of TS). Hence, the major contribution to the removal of organic matter in the form of BOD occurred in the equalization tanks, predominantly biological degradation units, which proves that the ST-ANF system functioned as decanters, predominantly.

The reduced concentration of suspended solids in the tributary and effluent of the stabilization tanks (points 2 and 3) (Table 1) imply a lower turbidity of the liquid under treatment, a fact that contributes with greater transparency for the passage of sunlight, favoring an intense Photosynthetic activity with great oxygen production by algae (Sousa, Van Haandel, Cavalcanti, & Figueiredo, 2005). Thus, the best performance in the organic matter degradation (BOD) in this stage of the treatment can be justified.

In relation of SS parameter, the average affluent (Table 1), was also among the average used concentration reported in the literature, to domestic sewage, from 200-450 mg L^{-1} and it is less than the typical concentration of 400 mg L^{-1} (Von Sperling, 2014). Moura et al. (2011) found average value of SS of 236 mg L^{-1} in domestic sewage. Oliveira and Von Sperling (2005) found a value superior (435 mg L^{-1}) to the result observed in the research.

Furthermore, in the domestic sewage treatment with ST-ANF system, Moura et al. (2011) identified efficiencies near the results of this study, varying from 10 to 40% to removal of TS and SS between 71 and 88%. At wastewater treatment plant with ST-ANF system, studied by Oliveira and Von Sperling (2005), the average removal efficiency of SS was less than the observed at the present research which presented 66%.

The results of SS removal monitoring in PFA wastewater treatment are below the range 80-90% presented by Von Sperling (2014) in domestic sewage treatment with ST-ANF system. However, the average of SS in point 1 differs statistically from the other points, in which the averages are significantly equal. The effluent passes through the anaerobic treatment (point 2) and there is satisfactory removal when it is released in water courses (Table 1).

At point 3, the removal efficiencies of the parameters were lower than at point 2, with 7.4% for TS and 43% for SS. This shows that the optional treatment in the stabilization tanks had a better performance also in SS removal. The mean of SS in point 3 differs statistically and is lower than the limit established by the legislation. It is noteworthy that in the stabilization tanks, the highest percentage of solids was dissolved. Thus, the higher efficiency in SS removal is mainly due to the lower concentration of SS in the liquid treatment.

The wastewater treatment plant with facultative lagoons evaluated by Oliveira and Von Sperling

(2005) presented 48% average in removal efficiency of SS, which is close to the value found in the present study. Nevertheless, it is observed in the treatment from PFA a greater performance for solid removal at anaerobic phase of treatment (ST-ANF) than at facultative phase (stabilization tanks). The same fact was verified in the study of these authors comparing ST-ANF and facultative lagoons.

As the effluent discharge standards were already met in phase 2 of the treatment, at point 3 the SS concentration continues within the discharge patterns in water bodies. It should be pointed out that as it is a stabilization pond, the specific norm of the state of Minas Gerais (Minas Gerais, 2008) establishes a limit of the highest maximum concentration of SS, of 150 mg L^{-1}, for the discharge of effluents in water bodies.

The average values of phosphorus concentrations (TP) and nitrogen nutrients (TKN) presented in wastewater from the kennel (point 1) (Table 1) are more elevated than the values observed in wastewater from swine, according to average results found by Pereira, Campos, and Moterani (2010) with TP and TKN of 1.1 and 69 mg L^{-1}, respectively.

The concentration of nutrients in the effluent from PFA (Table 1) also are larger than the values for domestic sewage studied by Moura et al. (2011), 15.9 mg L^{-1} of TP and 39.7 mg L^{-1} of TKN; and Oliveira and Von Sperling (2005), 8.0 mg L^{-1} of TP and 66,0 mg L^{-1} of TKN. The results obtained by these authors are practicality within the variation rage of (4-15 mg L^{-1}) with typical value of 7.0 mg L^{-1} and TKN (35-60 mg L^{-1}) with typical value of 45 mg L^{-1}, in domestic sewage, presented by Von Sperling (2014). This data is not compatible with the data observed in this research, which verified elevated TP and TKN concentration. Another important factor is the presence of major TKN concentration compared with TP in wastewater from swine and other sewages. In the effluent from PFA the major concentration is for TP between both nutrients (Table 1).

Considering swine manure, the animal food composition is related to the concentration of nutrients in the manure of those animals (Mello et al., 2012). It is used from 30 to 55% of nitrogen and from 20 to 50% of phosphate, which is ingested by the animals. The rest is excreted (National Research Council [NRC], 2012). Moreover, it is believed that, since they are monogastric, as well as swine, great amount of nutrients which are ingested by dogs are excreted in the feces and urine. Therefore, it may be inferred that the difference in nutritional composition of the effluents occurs due to the presence of elements in feeding and it leads to a conclusion that the source of elevated TP concentration is due to the composition of dog ration at PFA.

In the graphs (Figure 2g and h) it can be observed that there was a great deal of variation in TP concentration at points 2 and 3, presenting values even higher than point 1. In the case of concentrations at point 3, the variations were often shown higher than point 2. Thus, the efficiencies in TP removal were not satisfactory. Even when presenting better performance in point 2 (anaerobic treatment), in point 3 (optional treatment) there was no removal. The statistical test shows that there was no significant removal in the treatments, since the means of the three points do not differ statistically.

Moura et al. (2011) stated the efficiency of removal to TP varying from 9.8-86% in the treatment of domestic sewage with ST-ANF system. Oliveira and Von Sperling (2005) found average efficiency of 30% also in ST-ANF of several wastewater treatment plants. In addition, Von Sperling (2014) pointed out as removal limit of TP the value of 35%, in a domestic sewage treatment by ST-ANF. All of the reference values presented superior performance in the monitoring found of TP removal in ST-ANF system from PFA (Table 1).

In the treatment of facultative lagoons, the wastewater treatment plant evaluated by Oliveira and Von Sperling (2005) demonstrated average efficiency of 46% in TP removal, superior to ST-ANF treatments evaluated, different from the result from this research, which do not demonstrate efficacy of TP removal in facultative tanks (Table 1).

As there was no significant efficiency in the removal of PT in the facultative tanks, probably the increase of the nutrient concentration was due to accumulations and the decanting of total solids, and the PT contained in these.

As for TKN removal, the monitoring from this study presented a feeble performance, a fact that it is already know in relation to anaerobic treatment, which generally presents small removal of nutrients (Chernicharo et al., 2006). However, the results obtained at the present research are inferior to those found by Oliveira and Von Sperling (2005), an average of 24% for several wastewater treatment plant with ST-ANF, and by Moura et al. (2011), varying from 15 to 77% in treatment with the same anaerobic treatment system. In facultative lagoons, Oliveira and Von Sperling (2005) also verified efficiency of TKN removal, in average 44% higher than the present study (Table 1).

It is noteworthy here that concentrations in the kettle's wastewater, both TP and TKN, were higher than those observed by the aforementioned authors when evaluating domestic sewage treatment. Considering that the percentage of removal is relative to the input concentration, and that the higher the input concentration, the greater the anaerobic/facultative systems limitation in nutrient removal, the lower removal efficiencies were observed. Pereira et al. (2010), when treating swine effluents in anaerobic sludge blanket reactors, verified the removal of 7% of TKN, and an increase in effluent concentration of TP.

Vivan, Kunz, Stolberg, Perdomo, and Techio (2010) obtained 90% TKN removal in stabilization ponds (anaerobic-facultative-maturation) that received swine effluent pretreated in biodigesters with 2,832 mg L^{-1} of TKN. However, the authors showed that the majority of the removal was due to volatilization of the ammonia, because the pH of the system was higher than 8.5. According to Von Sperling (2014), at pH values lower than 8, practically all of the ammonia is in the ionized form (NH_4^+), not being susceptible to volatilization.

The study conducted by Vivan et al. (2010) showed high TP removal (98%) with a 960 mg L^{-1} influent TP concentration. Removal was attributed to physico-chemical removal by means of phosphorus precipitation due to high pH; The high transferability (sedimentation) is due to the high hydraulic residence time (approximately 170 days) and the low turbulence of the system. None of these factors were observed in this study. And because of the shorter hydraulic holding time and wide daily variation of the flow, the system suffered with the nutrient dragging of the same.

The mean vale of TKN of point 1 is lower and differs statistically from the other points, which presented larger and statistically equal means. This shows a large accumulation of nutrients from point 2, probably in the sludge of the ST-ANF system, which was transported according to the sudden variation of the inflow to the system.

Lamego Neto and Costa (2011) state that TKN and TP are generally conserved during the anaerobic treatment with an increase of mineralized fraction, thus contributing to a greater TKN concentration in point 2 (Table 1).

The phosphor incorporated to the slime may be removed by heterotrophic bacteria, which accumulate polyphosphates inside the cell, depending on favorable conditions to its growth and metabolism, hence the efficiency on phosphor removal. Despite its low concentration, it is still greater than nitrogen, as it occurred at point 2 in the treatment from PFA (Table 1) (Henrique, Sousa, Ceballos, & Brasil, 2010).

Due to the high concentrations of TKN at the exit of the treatment, with a statistically different mean and above the limit, the system does not meet the standards to release those effluents in watercourse (Figure 1). In relation to phosphor, the legislation does not establish standards for releasing effluents, only to monitor the phosphor considering the water quality, according to its use and classification. However, if there is high concentration of nitrogen in the release, as in the situation mentioned in this research, the value which extrapolates the established standards and the concomitant presence of high concentrations of phosphor will cause the eutrophication. This may initiate an exaggerated growth of algae and aquatic plants in the waterbody receptor. Thus, the removal of TP in the treatment must be considered to avoid negative impact on waterbody receptor.

For both total coliforms (CT) and thermotolerant (CF), the values observed in the present study (Table 1) were higher than average data of domestic sewage analyzed by Moura et al. (2011), from 6.24×10^8 MPN 100 mL^{-1} to CT and 6.19×10^6 MPN 100 mL^{-1} to CF; and by Oliveira and Von Sperling (2005) from 2.6×10^7 MPN 100 mL^{-1} to CF. Furthermore, it was was observed higher concentrations than the usual for domestic sewage from 10^6-10^9 MPN 100 mL^{-1} to CF (Von Sperling, 2014).

The numbers of this work are still higher in relation to wastewaters from swine, of which Duda and Oliveira (2011) found values of total and thermotolerant coliforms ranging from 7.4×10^6 to 1.6×10^8 NMP 100 mL^{-1}. These differences can be influenced by the dilution of waste in discarded waters. For domestic sewage this dilution is greater and in cases of animal wastewater the dilution depends on the cleaning and handling procedures of the breeding facilities.

In the graphs (Figure 2i and j) it can be observed that during the monitoring period, coliform values were, on average, higher at point 1, but showed many variations due to the procedures of washing the bays. This may have influenced the lower removal efficiencies of pathogenic microorganisms. In addition, it is known that the treatment of anaerobic units have reduced coliform removal efficiency. The removal in the equalization tanks would depend on lower concentration of organic matter, higher pH value and lower concentration of SS, in order to favor disinfection by means of natural ultraviolet radiation.

In the phase of anaerobic treatment with ST-ANF (point 2) the removal efficiency of coliforms was greater than the facultative phase (point 3)

(Table 1), however inferior to the records so far in literature about domestic sewage. Oliveira and Von Sperling (2005) verified average efficacy of 79% (0.9 unities log) to CF in several wastewater treatment plant using ST-ANF system. Von Sperling (2014) presented as typical removal the range of 1 to 2 unities logarithmic to ST-ANF system with domestic sewage. Considering this range as the value of efficiency over 80%, the result of this study to CF is close to the ideal for sewage in septic tank-anaerobic filter system (Table 1).

The efficiency of coliform removal in the facultative process, in tanks of stabilization (point 3), were lower (Table 1), on the contrary of the evaluation of Oliveira and Von Sperling (2005) in several wastewater treatment plants. According to the authors, the average efficiency of CF removal in facultative lagoons was 97% (1,6 logarithmic unities), greater than the anaerobic treatment in ST-ANF, which was also evaluated by the authors.

The statistical test shows that there was no significant removal in the treatments for both CT and CF, since the means of the three points did not differ statistically.

In relation to coliforms, the present environmental norms do not establish standards to release effluents in watercourse. to the standards are only to monitor the coliform regarding water quality, according to its use and classification. However, if there is elevated concentration of coliforms in the release, as found in the effluent, the release becomes inappropriate and it lacks proper adjustment in the system. Therefore, the treatment is not satisfactory and the release of the effluent presents high level of pollution.

The concentration of metals in dogs' manures is related to the feed composition of these animals, therefore the presence of Cu and Zn in the ration consumed by dogs from PFA influeces the concentration of those elements in the effluent, which presented greater concentrayions of Zn in comparision to Cu (Table 1). This fact it is due to a major presence of Zn (225 mg kg^{-1}), in the ration of dogs from PFA, in relation to Cu (13 mg kg^{-1}).

The oscillation of the concentrations probably occurs due to the procedures of washing the bays, which influence the dilution of wastes composed of these metals. There was a reduction in the concentration of Zn throughout the treatment and for Cu, the concentration was maintained in point 3, affecting the efficiency of removal of this parameter in the optional treatment in the stabilization tanks.

The averages of metals at point 1 differ statistically from the other points, in which the means are statistically the same. This shows that the phase of anaerobic treatment with ST-ANF system (point 2) presented greater performance in removal of both elements. Furthermore, the removal of Zn was more efficient in the point 2 and 3 of the treatment.

However, the average concentrations of the two metals in the effluent differ statistically and are lower than the limit, therefore, they meet the standards for effluent release, even without the need for treatment (Table 1).

Conclusion

Despite the low organic charge found in the effluent from PFA, the efficacy of removal in the treatment system was not satisfactory, even in nutrients, pathogens and detergents, presenting violation of the values permitted to release in water body, resulting in the negative alteration of the condition and patterns of the river Santa Cruz.

However, the performance in the removal of solids in the system was efficient according to the standard for releasing, especially in the anaerobic phase, evidencing that the ST-ANF system, especially for the septic tank, according to the literature showed about physical removal, functions as decant-digesters and, to a lesser extent, promote organic removal.

It was observed the necessity of increment in the aerobic phase in the system of treatment, after the anaerobic phase (ST-ANF), which potentiates the removal of organic matter, nutrients and detergents detected in the effluent. Moreover, this increment may present certain reduction in the amount of coliforms.

Thus, the stabilization tanks in sequence of aerobic treatment will receive the wastewater with lower concentration of organic matter and detergent, higher pH and lower SS concentration, in order to favor an efficient disinfection through natural (solar) ultraviolet radiation. In addition, this may complete the removal of nutrients without accumulation of slime, due to the lower concentration of solids.

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