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QUALITY OF EFFLUENT OF PISCICULTURE TREATED BY AEROBIC AND ANAEROBIC BIOLOGICAL FILTERS TO BE USED IN IRRIGATION

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1 ABSTRACT

Fish farming depends on environmental products and services for their sustainability, such as effluent and waste dilution capacity and availability of good quality water. The environmental problems related to the practice of this activity have to do with the water quality of effluents from fishponds that have organic matter, suspended solids and high concentrations of nutrients. Therefore, the objective of the present study was to analyze the quality of pisciculture effluents treated by two biological filters for release or use in agriculture. The experiment was conducted at the IFGoiano, Rio Verde campus, where two fish farming systems were built, with two different biological filters, the aerobic gravel filter (FB) and the anaerobic bamboo filter (FA), where collections were made at the exit of each one to verify the effluent quality for release and / or irrigation purposes. A completely randomized experimental design was used, in a 2×4 split-plot arrangement, and with three replications. The treatments consisted of four collection times, after the implementation of the experiment (60, 70, 80, and 90 DAI) and two filter types (anaerobic bamboo filter; and aerobic stone filter). The quality of the treated effluent was analyzed in the laboratories of Hydraulic and Irrigation; Sanitation and Environment; and Water and Effluents of the GFI-RV. The parameters evaluated were: electrical conductivity, total dissolved solids, pH, turbidity, alkalinity, chemical oxygen demand (COD), dissolved oxygen (DO), and biochemical oxygen demand (BOD). The parameters pH, total dissolve solids, turbidity, DO, and BOD were in accordance with the standards established by the CONAMA 357/05 for Class II waters (allowing use for irrigation of vegetables and fruit plants).

Keywords: Aquaculture, water resources, reuse, release.

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QUALIDADE DO EFLUENTE DE PISCICULTURA TRATADO POR FILTROS BIOLÓGICOS (AERÓBIO E ANAERÓBIO) PARA SER USADO NA IRRIGAÇÃO

2 RESUMO

A piscicultura depende de produtos e serviços ambientais para a sua sustentabilidade, tais como capacidade de diluição de efluentes e resíduos e disponibilidade de água de boa qualidade. Os problemas ambientais relacionados com a prática desta atividade, tem a ver com a qualidade da

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água dos efluentes de viveiros de peixes que apresentam matéria orgânica, sólido em suspensão e altas concentrações de nutrientes. Desta forma, objetivou-se analisar a qualidade do efluente de piscicultura ao passar por dois diferentes filtros biológicos para fins de lançamentos ou aproveitamento na agricultura. O trabalho foi conduzido no IFGoinao - Campus Rio Verde, onde foram construídos dois sistemas de piscicultura, com dois diferentes filtros biológicos, sendo o filtro aeróbio de brita (FB) e o filtro anaeróbio de bambu (FA), onde se realizou coletas na saída de cada um para se verificar a qualidade do efluente para fins de lançamento e/ou irrigação. O delineamento experimental utilizado foi inteiramente casualizado, analisado em esquema de parcelas subdivididas 2 × 4, com três repetições. Os tratamentos são quatro épocas de coletas após a instalação (60, 70, 80 e 90 DAI) e dois tipos de filtros (filtro anaeróbio de bambu e filtro aeróbio de brita). Avaliou-se parâmetros físico-químicos: turbidez, pH, alcalinidade, condutividade elétrica, demanda química de oxigênio (DQO), demanda bioquímica de oxigênio (DBO), oxigênio dissolvido (OD) e Sólidos Dissolvidos Totais (SDT). Em geral, pode se concluir que os parâmetros pH, SDT, turbidez, OD e DBO se enquadraram na resolução CONAMA 357/05, para classe II (permitindo o uso para irrigação de hortaliças e plantas frutíferas).

Palavras-chave: Aquicultura, recursos hídricos, reuso, lançamento.

3 INTRODUCTION

Water is the most important element for life, which when accessible and clean becomes indispensable for all life on earth (SILVA, 2013). Widespread water scarcity, gradual destruction and worsening pollution of water resources in many regions of the world, along with the progressive realization of incompatible activities, have increasingly required integrated resource planning and management (OSTRENSKY; BORGHETTI; SOTO, 2008).

In the last decades, the set of human activities concomitant with the increasing demographic increase has stimulated awareness about the importance of natural resources, especially water resources, which include questions about their quality as well as their rational use, aiming at controlling losses and waste (DONCATO *et al.*, 2013). Therefore, the activities that depend on these resources for their development need greater concern, because besides relying on good quality water for its production, it is essential that any generated effluent be properly treated.

Water quality in any breeding is of paramount importance to the success of production, but in fish farming it is the main raw material of the process (LEIRA *et al.*, 2016). One of the environmental concerns about the practice of this activity is the degradation of water quality, causing eutrophication, oxygen depletion and siltation of water bodies, due to the high concentration of nutrients, organic matter and suspended solid (BUFORD *et al.*, 2003).

Thus, it is necessary that the quality of the effluents generated in fish farms be the best possible, so that impacts or changes caused to water bodies are minimized (SILVA; LOSEKANN; HISANO, 2013).

The use of fish farming effluent for agricultural purposes, for example, is an alternative that provides minimization of the impacts generated by this activity, according to Mehnert (2003) this is an alternative for controlling pollution of water bodies, making water available to crops., nutrient recycling and increased agricultural production.

The expansion of pisciculture under environmentally sustainable bases requires the development of efficient systems regarding water use and environmental impacts, which should be researched (SILVA; LOSEKANN; HISANO, 2013). Thus, considering the expressive increase of pisciculture activity, which is often done without adequate planning or monitoring, studies on this issue are necessary to propose economical methods for the use its effluents for other purposes, such as irrigation, or even for treatment of them to a point of compliance with the norms required for release of effluents, focusing on the rational use of water resources.

Therefore, the objective of the present study was to analyze the quality of pisciculture effluents treated by two biological filters for release or use in agriculture.

4 MATERIAL AND METHODS

The experiment was conducted at the Goiano Federal Institute, Rio Verde campus (IFGoiano-RV), located at the geographic coordinates 17°48'28"S and 50°53'57"W, with average altitude of 720 m. The average annual temperatures of the region vary from 20 to 35 °C, and the average annual rainfall depths vary from 1.500 to 1.800 mm. The climate of the region is Aw tropical, according to Köppen (2013), with a rainy season from October to May, and a dry season from June to September.

A completely randomized experimental design was used, in a 2×4 split-plot arrangement, and with three replications. The treatments consisted of two filter types (anaerobic bamboo filter; and aerobic stone filter) and four collection times (60, 70, 80, and 90 days after the implementation of the experiment- DAI).

The tanks consisted of two 500-liter PVC boxes, and the filters and decanters consisted of 60-liter PVC drums.

The decanters were built in the interior of the filters, using two funnels with 15 cm diameter, two PVC elbows, and two 17-centimeter PVC pipes (32 mm diameter each) that had the function of capturing the effluent through the funnel installed inside the 60-liter PVC drum, allowing to direct the effluent to the entry of the filter, with outlet located at a height of 26 cm from the bottom of the decanter.

Approximately 8 kg of adult tilapias were placed in each tank, totaling 40 fishes per tank, which were fed with extruded feed (feed processed through pressure, resulting in strings of feed) during the experiment. The main components of the feed were crude protein (360 g kg^{-1}), crude fiber (60 g kg^{-1}), mineral matter (140 g kg^{-1}), calcium (25 g kg^{-1}); phosphorus (6.000 mg kg^{-1}), copper (8 mg kg^{-1}), manganese (15 mg kg^{-1}), zinc (80 mg kg^{-1}), and iron (60 mg kg^{-1}).

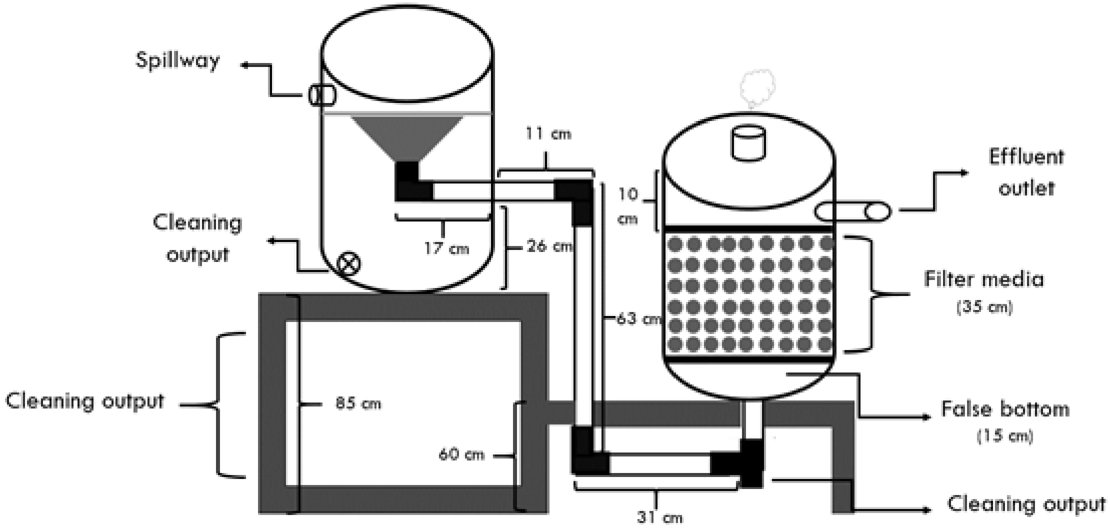
The water was recirculated in the tanks by using submerged hydraulic pumps of 30 W (Sarlo Better Sb 2000) with flow of 1950 L h^{-1}, manometric height of 2.1 m, and outlet height of 20 mm.

The decanter outlet to the anaerobic bamboo filter had horizontal and vertical conductors of 11, 63, and 31 cm that were made of 32 mm diameter PVC pipes and three 90-degree curves made of 2 PVC elbows and 1 32 mm diameter PVC tee, with an inlet to the filter located at the bottom part of the drum and with ascendant flux.

The bottom of the anaerobic bamboo filter had a suspended structure made of 32 mm diameter PVC pipes and a hexagonal-hole mesh, at a height of 15 cm, allowing uniformly the contact of the effluent with the filter media. The filter media had a height of 35 cm and was composed of bamboo pieces that were cut with length of 5 cm each.

The upper part of the filter had a 10-centimeter space to allow accumulation and release of gases through a circular opening. Two 15×15 cm acrylic sheets were placed in this filter, one over the suspended bottom and other in the upper part before the effluent outlet to assist in the retention of solids. The filter outlet to the tank consisted of a horizontal PVC conductor of 50 mm diameter and 90 cm length to support the flow (Figure 1).

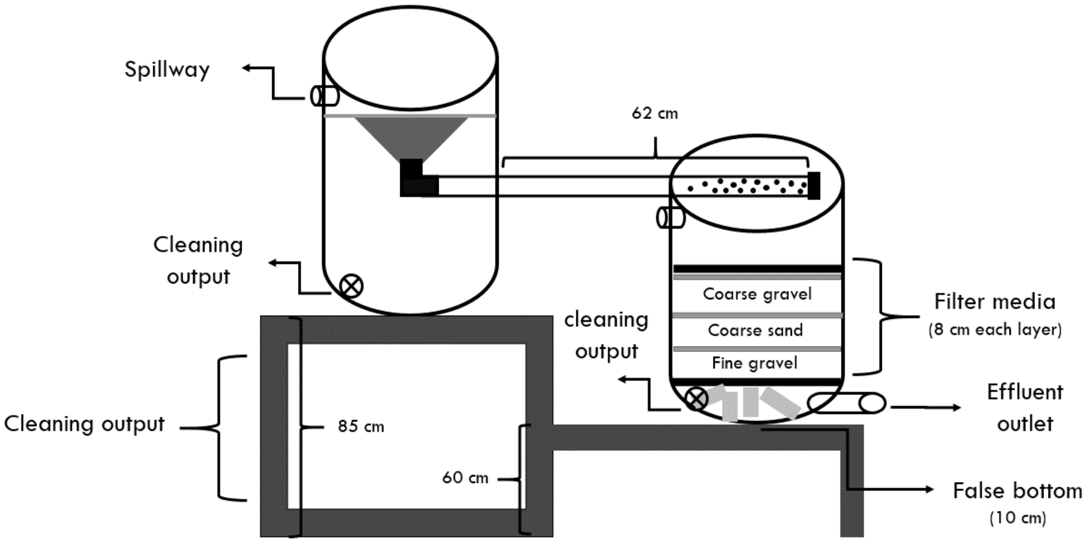
Figure 1. Model of the decanter system and the following anaerobic bamboo filter.



The decanter outlet to the inlet of the aerobic stone filter had a horizontal PVC conductor of 32 mm diameter and 62 cm length, which was irregularly perforated to allow the effluent entry into the filter through different points.

The aerobic stone filter works in a descendent direction, i.e., the effluent entries through the upper part and flows off through the lower part. It has a bottom made of several pieces of 32 mm diameter PVC pipes that were cut with length of 10 cm and placed irregularly in the bottom of the filter to allow the effluent to flow out without any obstruction. The layers of this filter, from bottom to top, were: 10 cm of PVC; fine screen; 8 cm of fine stone chips (4.8-9.5 mm); fine screen; 8 cm of coarse sand; fine screen; and 8 cm of coarse stone chips (19-25 mm), resulting in a filter media with 34 cm height (Figure 2).

Figure 2. Model of the decanter system and the following aerobic stone filter.



The water used for the system was subsurface water from wells that supply the local region. The results of the water physicochemical analysis are described in Table 1.

Table 1. Physicochemical characteristics of the subsurface water used in the experiment.

Subsurface water	
pH (NA)	7.90
Electrical conductivity (µS cm $^{-1}$)	250.30
Total dissolved solids (mg L^{-1})	137.66
Turbidity (NTU)	0.95
Alkalinity (mg L^{-1})	102.00

The physicochemical analysis of the pisciculture effluents begun at 60 DAI, which was the time determined for the formation of the biofilm in the filter media. Subsequently, the physicochemical characteristics of the effluent were analyzed every 10 days (70, 80, and 90 DAI).

The quality of the treated effluent was analyzed in the laboratories of Hydraulic and Irrigation; Sanitation and Environment; and Water and Effluents of the GFI-RV. The parameters evaluated were: pH, electrical conductivity, total dissolved solids, turbidity, alkalinity, dissolved oxygen (DO), biochemical oxygen demand (BOD), and chemical oxygen demand (COD).

Effluent samples were collected for analysis with three replications, using 500-milimeter glass flasks that were washed under the same water to be collected. The samples for DO and BOD analyses were collected in sterilized 300-milimeter Winkler bottles.

Regarding the methods used to the analyses, pH, electrical conductivity, total dissolved solids, turbidity, alkalinity, DO, BOD, and COD were evaluated according to the Standard Methods for the Examination of Water and Wastewater (APHA, 2005); pH was analyzed using an interactive portable pH-meter (LUCA-210P), electrical conductivity by a bench electrical conductivity meter (Mca 150), and the turbidity by a turbidity meter (HACH 2100 P). The average temperature of the effluent was monitored during the evaluations by using a thermometer installed in the tanks, and resulted in approximately 18°C.

The Brazilian federal legislation developed by the Brazilian National Environment Council (CONAMA) in their Resolutions 357/05 and 430/11 were considered. The Resolution 357/05 describes the classification of water bodies and the environmental guidelines for their fit and stablishes conditions and standards for release of effluents. The standards for Class II waters were considered for comparisons because these waters may be used for aquiculture and fishing, have similarity to the effluent analyzed in the present study, and may be used for irrigation of vegetable crops and fruit tree plants. The Resolution 430/11 describes the conditions and standards for release of effluents and complements and alters the Resolution 357/05.

The data obtained were subjected to analysis of variance by the F test ($p<0.05$); when significant, the means were subjected to regression analysis for the collection times, and to the Tukey's test ($p<0.05$) for the filter types, using the Sisvar program (FERREIRA, 2011).

5 RESULTS AND DISCUSSION

The analysis of variance showed no significant interaction ($p<0.01$) between the factors—filters and days after the implementation (DAI) of the experiment—for pH and alkalinity. The factor DAI was significant ($p<0.01$) for electrical conductivity and total dissolve solids. The highest coefficient of variation of the variables was 10.6% (Table 2). Silva (2007) also found significant differences for physicochemical parameters in pisciculture tanks ($p<0.05$).

Table 2. Analysis of variance for pH, electrical conductivity (EC), total dissolved solids (TDS), alkalinity (ALK) of pisciculture waters.

SV	DF	MS^1			
		pH	**EC**	**TDS**	**ALK**
Filters	1	0.78^{ns}	462.88^{ns}	140.02^{ns}	6435.37**
Residual (a)	2	0.07	137.84	41.71	7.87
DAI	3	0.40**	11677.78**	3532.67**	15550.26**
Filters*DAI	3	0.18**	274.57^{ns}	83.03^{ns}	4775.71**
Residual (b)	14	0.02	1698.76	513.87	6.40
CV a (%)		3.63	3.02	3.02	3.02
CV b (%)		1.86	10.60	10.60	2.72

^{1}Days after the implementation (DAI); Source of variation (SV); degree of freedom (DF); Mean square (MS) and coefficient of variation (CV). * significant at 5% by the F test; ** significant at 1% by the F test and ^{ns} not significant at 5% by the F test.

The interaction between the factors was significant ($p<0.01$) for turbidity and dissolved oxygen (DO). The factor DAI was significant ($p<0.01$) for biochemical oxygen demand (BOD) and chemical oxygen demand (COD). The mean coefficient of variation for these variables was 16.86% (Table 3). Silva (2007) compared quality parameters of pisciculture waters and found significant differences ($p<0.05$) for alkalinity and BOD.

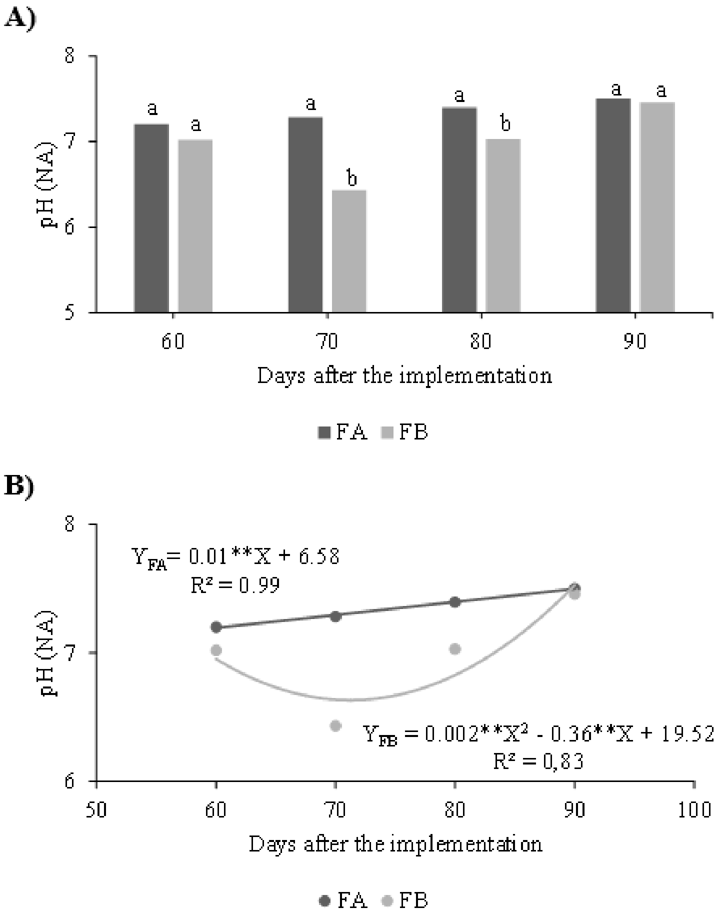
Table 3. Analysis of variance for turbidity (TUR), dissolved oxygen (DO), biochemical oxygen demand (BOD), and chemical oxygen demand (COD) of pisciculture waters.

SV	DF	MS[1]			
		TUR	DO	BOD	COD
Filters	1	88.78^{**}	26.88^{*}	3.30^{*}	3875.02^{ns}
Residual (a)	2	0.05	0.32	0.07	1288.29
DAI	3	1.94^{**}	70.08^{**}	14.94^{**}	19396.53^{**}
Filters*DAI	3	11.90^{**}	12.89^{**}	0.53^{ns}	627.22^{ns}
Residual (b)	14	0.31	0.64	0.65	783.65
CV a (%)		3.11	5.31	7.43	29.14
CV b (%)		6.18	19.19	18.83	22.73

[1] Days after the implementation (DAI); Source of variation (SV); degree of freedom (DF); Mean square (MS) and coefficient of variation (CV). * significant at 5% by the F test; ** significant at 1% by the F test and ^{ns} not significant at 5% by the F test.

The pH of the pisciculture effluent (pH_{PE}) in the anaerobic bamboo filter did not differ significantly from that in the aerobic stone filter at 60 and 90 DAI (Figure 3A).

Figure 3. pH of pisciculture effluents as a function of filters (A) and as a function of days after the implementation of the experiment, for the anaerobic bamboo filter and aerobic stone filter (B).



Means followed by the same letter are not different by the Tukey's test at 5% probability. ** F value significant at 1% of probability.

The pH_{PE} in the anaerobic bamboo filter at 70 DAI was 11.67% higher than that in the aerobic stone filter. The pH_{PE} in the anaerobic bamboo filter at 80 DAI was 4.95% higher than that in the aerobic stone filter (Figure 3A). Both filters are in accordance with the standards stablished by the CONAMA 430/11, which is between 5 and 9 for release of effluents of any source (BRASIL, 2011).

Although the pH of the effluents evaluated was within the standard range for release or rearing of fishes, which is 6 to 9 (LEIRA *et al.*, 2016), the highest variation between filters (11.67%) may be explained by the nutrient concentrations in the effluents. According to Beveridge, Phillips and Clarke (1991), Talbot and Hole (1994) and Macedo and Sipauba-Tavares (2010), nutrient concentration in pisciculture effluents may cause variations in pH.

The pH_{PE} as a function of DAI for the anaerobic bamboo filter fitted to a linear regression model, with R^2 of 99% (Figure 3B).

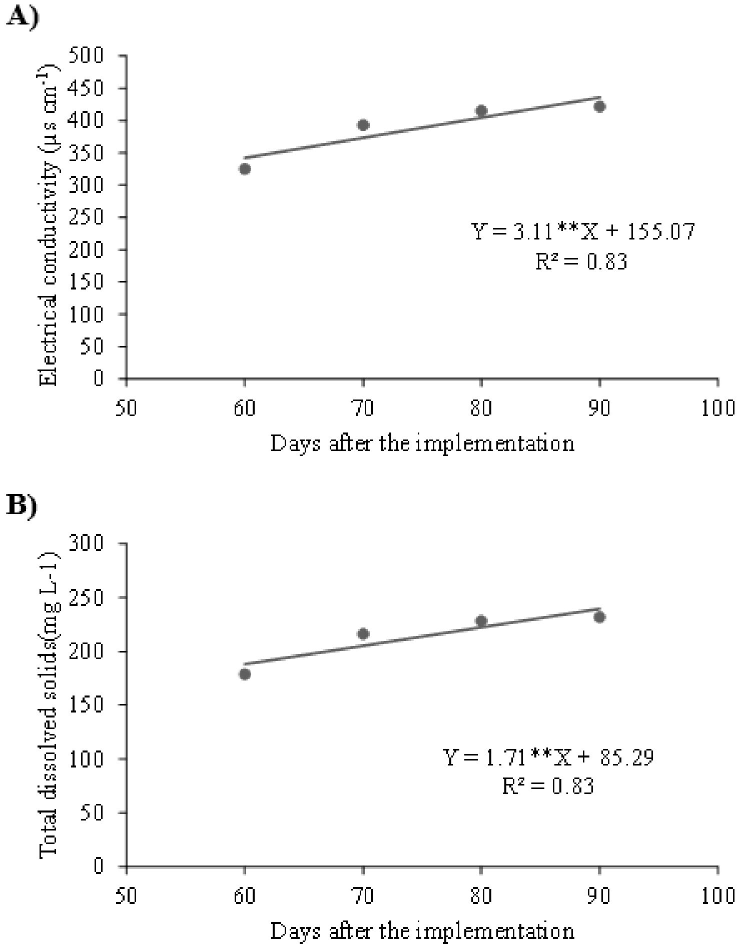
The increases in DAI increased the pH_{PE} up to 90 DAI, when the highest pH_{PE} (approximately 7.49) for the anaerobic bamboo filter was found. This highest pH_{PE} at 90 DAI was 4.04%, 2.69%, and 1.34% higher than those at 60, 70, and 80 DAI, respectively. Consequently, according to the regression equation, it increased approximately 1.35% every 10 days (Figure 3B). Piratoba *et al*. (2017) found similar pH, with means of 7.01 to 7.18.

The pH_{PE} as a function of DAI for the aerobic stone filter fitted to a quadratic regression model, with R^2 of 83%.

The pH_{PE} decreased with increasing DAI up to 72 DAI, when the lowest pH_{PE} (approximately 6.41) for the aerobic stone filter was found (Figure 3B). The pH_{PE} at 72 DAI was 5.67%, 2.19%, and 10.74% lower than those at 60, 80, and 90 DAI, respectively (Figure 3B). Considering the pH found, this effluent can be used in agriculture at any DAI; according to the CONAMA 357/05, waters for irrigation of vegetable crops and fruit tree plants must fit to the Class II waters, whose standard pH is 6 to 9 (BRASIL, 2005).

The electrical conductivity of the pisciculture effluents for both filters evaluated as a function of DAI fitted to a linear regression model, with R^2 of 83% (Figure 4A).

Figure 4. Electrical conductivity (A) and total dissolved solids (B) of pisciculture effluents as a function of days after the implementation of the experiment.



** F value significant at 1% of probability

The increases in DAI increased the electrical conductivity of the pisciculture effluents up to 90 DAI, when the highest electrical conductivity was reached, which was of approximately 435.39 µS cm^{-1}. The highest electrical conductivity found in the pisciculture effluents at 90 DAI was 21.46%, 14.30%, and 7.15% higher than those at 60, 70, and 80 DAI, respectively. According to the regression equation, it represented increases of approximately 7.15% for each 10 days (Figure 4A).

According to Von Sperling (2007), the legislation does not describe standards for electrical conductivity; however, the electrical conductivity of polluted environments by effluents can reach 1000 µS cm^{-1}. According to Ayers and Westcot (1991), waters with electrical conductivity lower than 700 µS cm^{-1} present no restriction for irrigation uses. Thus, regarding electrical conductivity, this effluent can be used in agriculture at any DAI.

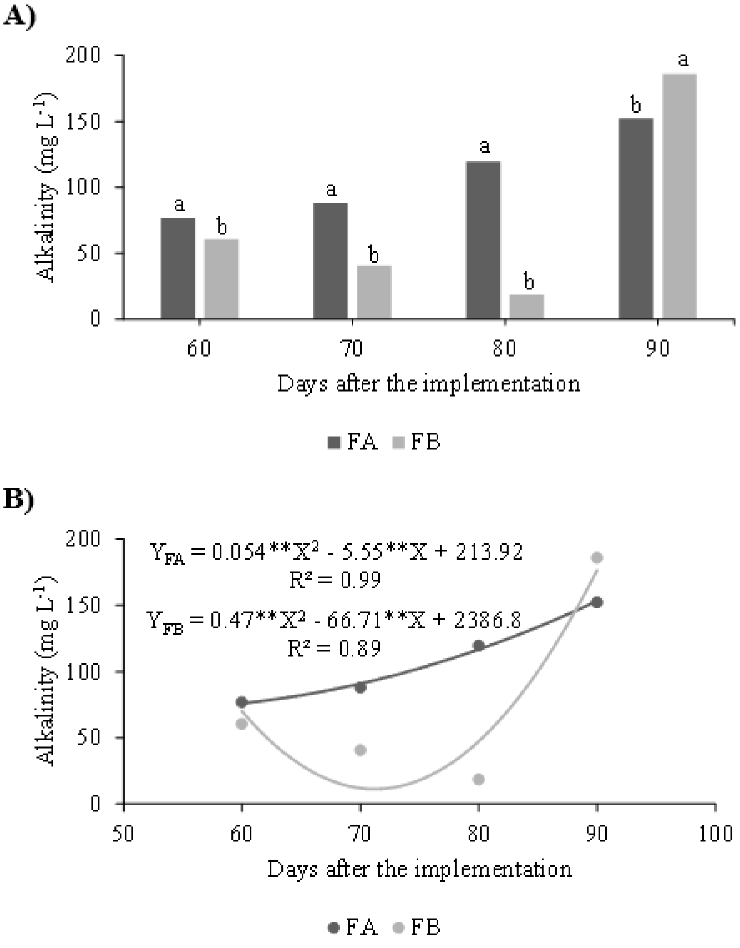
The total dissolve solids (TDS) of the pisciculture effluents as a function of DAI fitted to a linear regression model, with R^{2} of 83% (Figure 4B).

The increases in DAI increased the TDS of the pisciculture effluents up to 90 DAI, when the highest TDS was reached, which was of approximately 239.47 mg L^{-1}. The highest TDS of the pisciculture effluents at 90 DAI was 21.46%, 14.30%, and 7.15% higher than those at 60, 70, and 80 DAI, respectively. According to the regression equation, it represented increases of approximately 7.15% for each 10 days (Figure 4B).

The TDS concentrations of all DAI were lower than 500 mg L^{-1}, which is within the standards of quality established by the CONAMA 357/05 for waters of Classes I, II, and III, indicating quality for use in irrigation of vegetable crops and fruit tree plants (BRASIL, 2005).

The alkalinity levels of the pisciculture effluents in the anaerobic bamboo filter were 21.21%, 53.79%, and 84.40% higher than those in the aerobic stone filter at 60, 70, and 80 DAI, respectively (Figure 5A).

Figure 5. Alkalinity of pisciculture effluents as a function of filters (A) and of days after the implementation of the experiment for the anaerobic bamboo filter (ABF) and aerobic stone filter (AST) (B).



Means followed by the same letter are not different by the Tukey's test at 5% probability. ** F value significant at 1% of probability.

The alkalinity of the effluent at 90 DAI in the aerobic stone filter was 18.10% higher than that in the anaerobic bamboo filter (Figure 5A). According to Lomas, Urbano and Camarero (2000), the recirculation of effluent in anaerobic reactors intends to promote microbial growth and increase the effluent alkalinity, which was found up to 90 DAI.

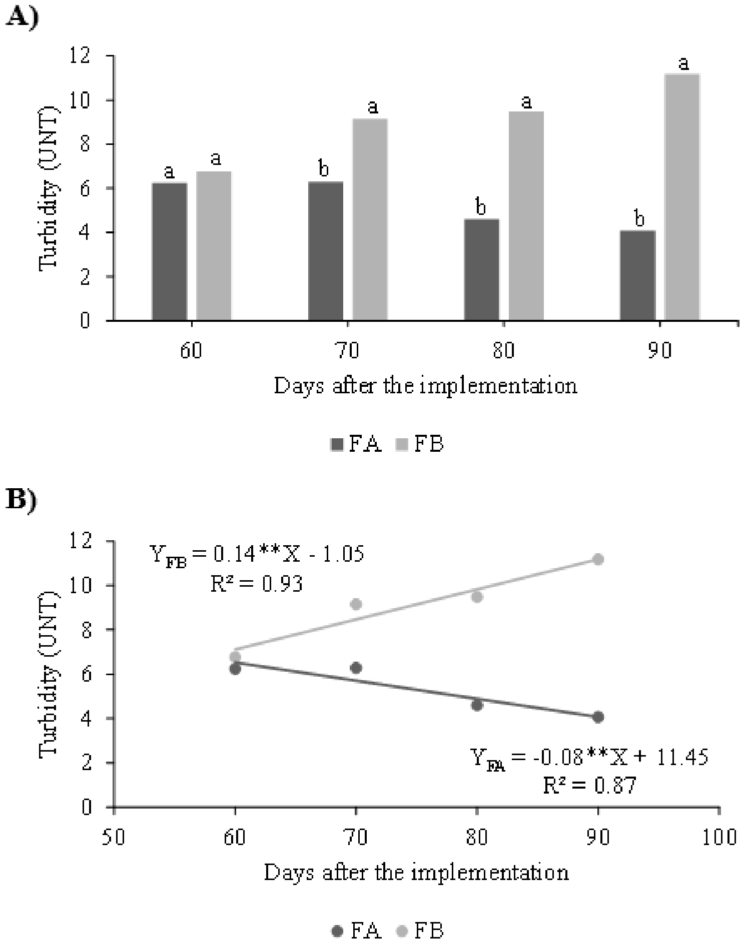
The alkalinity of the pisciculture effluents as a function of DAI for both filters evaluated fitted to a quadratic regression model, with R^2 above 89% (Figure 5B).

The alkalinity of the pisciculture effluents decreased with increasing DAI up to 60 and 71 DAI, when the lowest alkalinity levels were found, which were 71.93 and 11.06 mg L^{-1} for the anaerobic bamboo filter and aerobic stone filter, respectively. The alkalinity of the effluent of the anaerobic bamboo filter at 60 DAI was 16.43%, 34.88%, and 50.43% lower than those at 70, 80, and 90 DAI, respectively (Figure 5B).

The alkalinity of the effluent of the aerobic stone filter at 71 DAI was 84.21%, 76.51%, and 93.71% lower than those at 60, 80, and 90 DAI, respectively (Figure 5B). Felizatto (2000) found a lowest alkalinity of 83 mg L^{-1} in samples of pisciculture tank effluents.

The turbidity of the pisciculture effluents of the two evaluated filters presented no significant difference at 60 DAI (Figure 6A).

Figure 6. Turbidity of pisciculture effluents as a function of filters (A) and of days after the implementation of the experiment, for the anaerobic bamboo filter (ABF) and aerobic stone filter (ASF) (B).



Means followed by the same letter are not different by the Tukey's test at 5% probability. ** F value significant at 1% of probability.

The turbidity levels of pisciculture effluents of the aerobic stone filter at 70, 80, and 90 DAI were 31.29%, 51.46%, and 63.59% higher than those of the anaerobic bamboo filter (Figure 6A). Cezar *et al.* (2003) found that the ascendant filtration was efficient to remove turbidity; and Souza, Isoldi and Oliz (2010) pointed out a great retention of solids by an anaerobic bamboo filter, denoting that the filter media had filtration properties.

The turbidity of the pisciculture effluents as a function of DAI fitted to a linear regression model, with R^2 of at least 87% (Figure 6B).

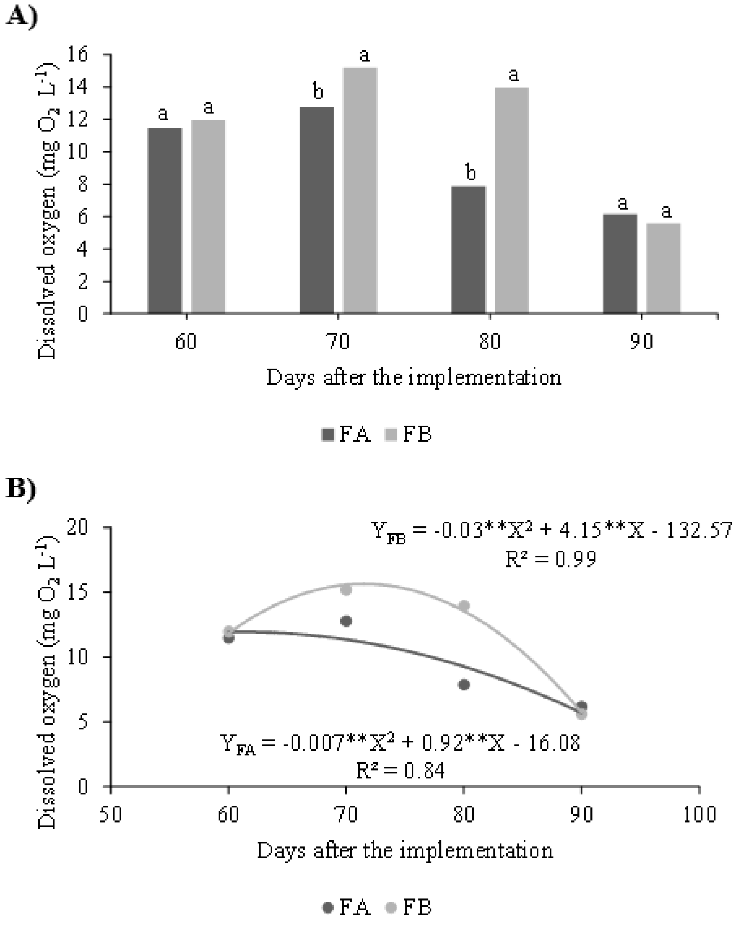
The increases in DAI increased the turbidity of the pisciculture effluents of the aerobic stone filter up to 90 DAI, when the effluent reached the highest turbidity, approximately 11.18 NTU. This highest turbidity of the pisciculture effluent at 90 DAI was 36.46%, 24.31%, and 12.15% higher than those at 60, 70, and 80 DAI, respectively. According to the regression equation, it represented increases of approximately 12.15% for each 10 days (Figure 6B). The increasing turbidity found can be due to the rapid growth of the aerobic biomass, increasing the biofilm and making it to detach from the support layer.

The turbidity of the pisciculture effluents of the anaerobic bamboo filter decreased with increasing DAI up to 90 DAI, when the lowest turbidity was found, approximately 4.04 NTU. This lowest turbidity of the pisciculture effluent at 90 DAI was 12.54%, 25.09%, and 37.64% lower than that found at 60, 70, and 80 DAI, respectively. According to the regression equation, it represented a decrease of approximately 12.54% for each 10 days (Figure 6B).

The highest turbidity found by Fravet and Cruz (2006) was 15.33 NTU. Although the legislation does not stablish standards of turbidity for release of effluents, the highest turbidity described by the CONAMA 357/05 for Class II waters used for irrigation is of up to 100 NTU (BRASIL, 2005), denoting the fit of the effluents of both filters in all DAI to the standard established.

The dissolved oxygen (DO) concentrations of pisciculture effluents of the anaerobic bamboo filter and aerobic stone filter presented no significant differences at 60 and 90 DAI (Figure 7A).

Figure 7. Dissolved oxygen of pisciculture effluents as a function of filters (A) and of days after the implementation of the experiment, for the anaerobic bamboo filter (ABF) and aerobic stone filter (ASF) (B).



Means followed by the same letter are not different by the Tukey's test at 5% probability. ** F value significant at 1% of probability.

The DO concentrations of the pisciculture effluent of the aerobic stone filter at 70 and 80 DAI were 16% and 43.67% higher than those found in the effluent of anaerobic bamboo filter (Figure 7A).

The highest DO concentration found by Fravet and Cruz (2006) was 9.57 mg L^{-1}. According to the CONAMA 357/05 for Class II waters (for use in irrigation of vegetable crops and fruit tree plants), the DO of all samples must be lower than 5 mg L^{-1} (BRASIL, 2005). Thus, considering this parameter, the pisciculture effluents of both filters are in accordance with the standards established by the legislation.

The DO concentration in the pisciculture effluents as a function of DAI fitted to a quadratic regression model, with R^2 of at least 84% (Figure 7B).

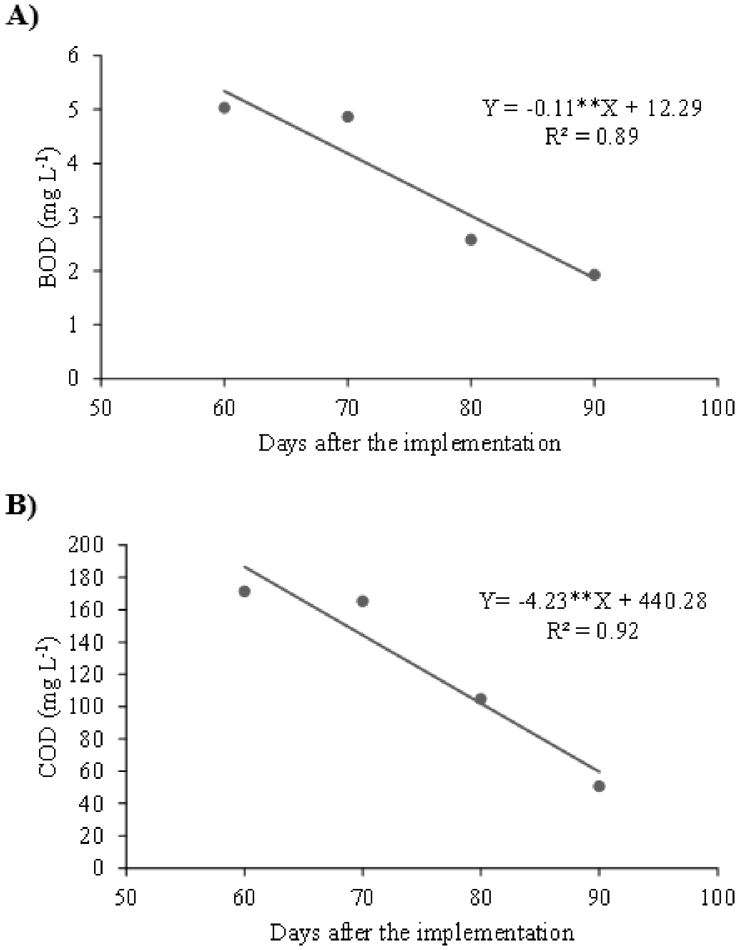
The increases in DAI increased the DO concentration of the pisciculture effluents up to 62 and 72 DAI, when the highest DO concentrations were found, which were 11.95 and 15.66 mg L^{-1} for the anaerobic bamboo filter and aerobic stone filter, respectively (Figure 7B).

The DO concentration in the pisciculture effluent of the anaerobic bamboo filter at 62 DAI was 4.93%, 22.35%, and 52.31% higher than those at 70, 80, and 90 DAI, respectively. The DO concentration in the pisciculture effluent of the aerobic stone filter at 72 DAI was 24.46%, 13.39%, and 63.40% higher than those at 60, 80, and 90 DAI, respectively (Figure 7B).

According to Fão (2013), water temperature has a great effect on the amount of DO; the lower the temperature, the grater the amount of oxygen in the water medium. This variation in DO concentration may be explained by variations in temperature, whose highest value was 20 °C at 90 DAI, when the lowest DO was found.

The BOD of the pisciculture effluents as a function of DAI fitted to a linear regression model, with R^2 of 89% (Figure 8A).

Figure 8. Biochemical oxygen demand (BOD) (A) and chemical oxygen demand (COD) (B) of pisciculture effluents as a function of days after the implementation of the experiment.



** F value significant at 1% of probability

The BOD of the pisciculture effluents decreased with increasing DAI up to 90 DAI, when the lowest BOD was found, approximately 1.93 mg L^{-1}. This lowest BOD at 90 DAI was 21.66%, 43.34%, and 65% lower than those at 60, 70, and 80 DAI, respectively. According to the regression equation, it represented a decrease in BOD of approximately 21.67% for each 10 days (Figure 8A).

The standard BOD established by the CONAMA 357/05 for Class II waters (for use in crop irrigation) is up to 5 mg L^{-1} (5 days at 20 °C) (BRASIL, 2005). Thus, considering this parameter, the pisciculture effluents evaluated are in accordance with the standards established by the legislation, except for those evaluated at 60 DAI, which presented a BOD of 5.03 mg L^{-1}. Similar results were found by Souza Filho and Maia (2017), who found BOD within the limits established by the Resolution CONAMA 357/2005 in all points of sampling of the pisciculture tank.

The COD of the pisciculture effluents as a function of DAI fitted to a linear regression model, with R^2 of 92% (Figure 8B).

The COD of the pisciculture effluents decreased with increasing DAI up to 90 DAI, when the lowest COD was found (approximately 50.78 mg L^{-1}). The lowest COD of the pisciculture effluents found at 90 DAI was 22.66%, 45.32%, and 67.98% lower than those at 60, 70, and 80 DAI, respectively. According to the regression equation, it represented a decrease of approximately 22.66% for each 10 days (Figure 8B).

The Resolution CONAMA 430/11, which complements and alters the CONAMA 357/05, does not establish the highest COD concentration for release of effluents into water bodies; and the CONAMA 357/05 does not stablish standards for fitting of this parameter to waters of Classes I and II, which comprise waters that can be used for irrigation. The highest COD found by Azzolini, Zardo and Segalin (2010) was 245 mg L^{-1} in a pisciculture tank without dewater.

6 CONCLUSION

The pH and alkalinity of pisciculture effluents tended to increase in the anaerobic bamboo filter, as well as the turbidity in the aerobic stone filter.

The electrical conductivity and total dissolve solids increased with increasing days after the implementation (DAI). The biochemical oxygen demand (BOD) and chemical oxygen demand (COD) showed decreases, regardless of the filter used.

The highest dissolved oxygen (DO) concentration was 11.95, and 15.66 mg L^{-1} for the anaerobic bamboo filter, and aerobic stone filter, respectively, at approximately 67 DAI.

Among the parameters evaluated and that are described by the Resolution CONAMA 430/11 for release of effluents, which complements and alters the CONAMA 357/05, only the pH was in accordance with the standards established.

The parameters pH, total dissolve solids, turbidity, DO, and BOD were in accordance with the standards established by the CONAMA 357/05 for Class II waters, which allows the use of waters for irrigation of vegetable crops and fruit tree plants; thus, these variables can also be considered for release into water bodies if the water body fit the legislation for Class II waters. Is important to consider that a bacteriological analysis is required before the use of effluents for irrigation of vegetable crops.

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