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Quality of a soil submitted to different times of irrigation with fish culture effluent

This study aimed to evaluate the quality of a soil subjected to different irrigation times with fish farming effluent in the western region of Bahia, Brazil. The study was carried out in 3 properties in the irrigated perimeter of São Desidério/Barreiras Sul: property that did not carry out fish farming activities (T1); with 5-year-old (T2) and 20-year-old (T3) nurseries, with cultivation mainly of Tambaqui (Colossoma macropomum). For the characterization of water quality, samples were collected from fishponds in T2 and T3 and from the supply channel. To assess soil quality, preserved and nonpreserved samples were collected. In the physicochemical analyses, the water from fish farming shows turbidity and increased levels of ammoniacal nitrogen in the effluents. There are changes in the porosity, soil density and height of water stored in the soil, indicating compacted soils. Decreased micronutrients and macronutrients suggest leaching losses. The proper management of the effluent and of the receiving soil is essential to enable the use of fish farming effluent in agricultural activity.

Keywords: Effluent; Physicochemical analysis; Tambaqui; Water quality.

Qualidade de um solo submetido a diferentes tempos de irrigação com efluente de pisciculture

Este estudo objetivou avaliar a qualidade de um solo submetido a diferentes tempos de irrigação com o efluente de piscicultura na região Oeste da Bahia, Brasil, sendo os tratamentos, três propriedades do perímetro irrigado de São Desidério/Barreiras Sul: T1: propriedade sem atividade de piscicultura; T2: propriedade com viveiros de cinco anos e T3: propriedade com viveiros de vinte anos de atividade, com cultivo principalmente de Tambaqui (Colossoma macropomum). Para a caracterização da qualidade da água, amostras foram coletadas dos viveiros de piscicultura em T2 e T3 e do canal de abastecimento. Para avaliação da qualidade do solo, foram coletadas amostras com estrutura preservadas e não preservadas. Nas análises físico-químicas, a água da piscicultura apresentau turbidez e níveis de nitrogênio amoniacal aumentados nos efluentes. Ocorreu alterações na porosidade, densidade do solo e altura de lâmina de água armazenada no solo, com indicação de solos compactados. A diminuição de micronutrientes e macronutrientes sugere perda por lixiviação. O manejo adequado do efluente e do solo receptor é fundamental para viabilizar o uso do efluente de piscicultura na atividade agrícola.

Palavras-chave: Efluente; Análises físico-químicas; Tambaqui; Qualidade da água.

Topic: **Ciências do Solo**

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INTRODUCTION

The growth of the world population has caused the demand for food to increase. Fish farming is important in the search for food security and nutritional quality of individuals, and for this reason, it is an area of great rise (GUILLEN et al., 2019). The western region of Bahia is the third largest producer of fish in the state and stands out in the first place in the cultivation of Tambaqui (*Colossoma macropomum*) in excavated lakes (PEIXE BR, 2019). The region has aptitude for the sustainable development of the activity due to climatic conditions, availability of water resources and public policies for its strengthening. This contributes to the production of food with high benefit and easy acceptance in national and international markets.

With the increase in productivity, the generation of volumes of effluents from fish farming grows, which can negatively impact the environment. Management strategies are essential to mitigate such effects. An alternative is the reuse for irrigation purposes of agricultural crops, which can increase production efficiency, serving as a complement to fertilization, with nutritional advantages for the irrigated crop and consequently for the economy and the environment.

In studies by Silva et al. (2018), the reuse of fish farming effluent in the irrigation of corn (*Zea mays*) positively influenced the development of the plant in relation to the treatment with the supply water. In common bean (*Phaseolus vulgaris*) cultivation, plant development was similar to that in plants irrigated with water.

To direct fish farming-agriculture integration through the reuse of effluents, it is necessary to evaluate the soil that will receive it and the quality of the effluent. In this study, physical-chemical analyses were carried out to determine the water quality of the fish farm effluent and the soil that received this effluent at different times of application to stimulate the sustainability of the local practice.

MATERIALS AND METHODS

In an entirely randomized design, with three repetitions, three properties located in the Irrigation Perimeter of São Desiderio/Barreiras Sul in Barreiras, Bahia, Brazil, were selected as treatments: T1: property with no fish farming activity; T2: property with five-year ponds; T3: property with twenty-year ponds of activity for evaluation of the effects of the time of use of fish farming effluents on the quality of a dystrophic red–yellow Latosol of sandy texture. The parameters of the water quality used in fish farming are presented in Table 1.

Soil samples with preserved and nonpreserved structures were collected in layers from 0.00 to 0.05; 0.05 to 0.10 and 0.10 to 0.20 m. Soil with preserved structures was collected in volumetric rings 4.8 cm in diameter and 5 cm in height, totaling 81 samples (3 rings per layer x 3 layers x 3 repetitions x 3 treatments), and soil with unpreserved structures was collected with a shovel, totaling 27 samples (3 samples x 3 layers x 3 treatments).

Soil grain size fractions (sand, silt and clay content), macroporosity (Ma), microporosity (MI), total porosity (TP), aeration porosity (AP), bulk density (Bd) and total organic carbon (TOC) were determined according to the methods described in Texeira et al. (2017).

Table 1: Parameters and methods used in the physical and chemical analysis of water.

Parameter	Methods	Methodological reference
Total Alkalinity	Titration	SMWW, 22ª Ed., 2320B
Chlorides	Argentometric	SMWW, 22ª Ed., 4500-Cl^- B
Total Phosphorus	Ascorbic acid	SMWW, 22ª Ed., 4500-P E
Ammoniacal Nitrogen	Flow injection analysis	SMWW, 22ª Ed., 4500-NH_3 H
Nitrate Nitrogen	Nitrate electrode	SMWW, 22ª Ed, 4500-NO_3 D
Nitrogen from Nitrites	Colorimetric	SMWW, 22ª Ed., 4500-NO_2 B.
Dissolved oxygen	Membrane electrode	SMWW, 22ª Ed., 4500-O G
Temperature	Electrometric	SMWW, 22ª Ed., 2550 B
Turbidity	Nephelometric	SMWW, 22ª Ed., 2130 B
Iron	Flame Atomic Absorption Spectrometry	SMWW, 22ª Ed., 3111 B
pH (25°C)	Electrometric	SMWW, 22ª Ed., 4500 B
Chlorophyll *a*	Gas chromatography coupled to mass spectrometry/Headspace	USEPA SW 846 - 8260 C, 5021 A.

*SMWW = Standard Methods for the Examination of Water and Wastewater (APHA et al., 2005).

The height of the water depth stored in the soil was calculated by relating the volumetric moisture and the dimension of each layer in the soil profile, according to the trapezoid rule (LIBARDI, 2005). The pH was quantified using a digital meter; the potential acidity (H+Al) was determined using a SMP solution (Shoemaker, Mac lean and Pratt method). The phosphorus was quantified using the Mehlich extractor, followed by reading in a spectrophotometer; the remaining phosphorus was quantified using an equilibrium solution, followed by filtration and reading in a microwave plasma spectrophotometer.

Sulfur was quantified by means of extraction solution followed by acid filtration and reading in spectrophotometer. Boron was quantified in heated hydrochloric acid solution followed by filtration and reading in microwave plasma spectrophotometer; copper, iron, manganese and zinc were quantified by means of Mehlich extractor; calcium, magnesium, potassium and sodium were determined using cationic and anionic resins with readings in a microwave plasma spectrophotometer. These were used to quantify the bases sum (SB), the cation exchange capacity (CEC) and bases saturation (V).

Data normality was assessed by the Shapiro–Wilk test ($n \leq 200$). Outliers were verified using measurements of the lower limit and upper limit, considering the first quartile, the third quartile and 1.5 of interquartile range and were replaced by the average of the values in the immediately superior and inferior positions. The results were submitted to analysis of variance, and the means were compared using Duncan's test ($p < 0.05$).

RESULTS AND DISCUSSION

The control of water quality in fish farming is important for the sustainability of the activity, as changes in its composition can affect the growth of organisms and even lead to their death. Additionally, they negatively impact the environment in which they are released. Alkalinity determines the water's potential to neutralize acids and is responsible for buffering the water's pH, preventing large pH variations. The ideal pH range for fish farming is between 6.5 and 9.0, and values that do not include this range can cause stress and damage animal development (CAVALCANTE et al., 2010). There were no considerable changes in alkalinity levels when compared to water from the supply channel and fish farming ponds, and the pH was in the range (Table 2). According to Leira et al. (2017), water alkalinity values between 20 and 300 mg mL^{-1} are necessary for fish farming.

Table 2: Physical-chemical and biological analysis of effluent water and fish farming supply.

Parameter	Supply channel	Property T2	Property T3
Alkalinity (mg L^{-1})	128.0	123.0	105.0
Chlorides (mg L^{-1})	9.9	12.6	15.3
Total Phosphorus (mg L^{-1})	0.21	0.33	0.57
Ammoniacal Nitrogen (mg L^{-1})	0.90	3.14	1.41
Nitrate Nitrogen (mg L^{-1})	<0.23	<0.23	<0.23
Nitrogen from Nitrites (mg L^{-1})	<0.02	<0.02	<0.02
Dissolved oxygen (mg L^{-1})	7.7	7.28	9.31
Temperature (°C)	30.9	29.1	29.7
Turbidity (UNT)	24.7	116.0	207.0
Iron (mg L^{-1})	0.23	1.31	2.63
pH 25°C (Adi)	7.65	7.68	7.64
Chlorophyll *a* (µg L^{-1})	<4.7	8.5	7.4

T2: property with fish farming activity for 5 years; T3: property with fish farming activity for 20 years.

The optimal temperature range for fish farming in Brazil is 26°C to 30°C. Out-of-range values can reduce appetite, slow growth, and make fish more susceptible to infections. The water temperature in the study matches expectations.

The dissolved oxygen concentrations in the evaluated waters are desirable for fish farming (above 5 mg L^{-1}). However, an increase in turbidity was observed in properties T2 and T3 in relation to water from the supply channel. Studies conducted by Ibearugbulam et al. (2021) associate similar results with inadequate management of cultivation facilities and low frequency of water renewal, resulting in increased waste in the effluent.

Ammonia nitrogen in T3 and in the water supply are considered optimal according to the levels established by the National Council for the Environment - CONAMA (BRASIL, 2005). However, the T2 content is not desirable for fish farming.

Regarding the conditions and standards of effluent discharge, CONAMA resolution 430/2011 determines that the maximum ammonia nitrogen limit is 20.0 mg L^{-1} (BRASIL, 2011), with the samples evaluated in agreement. Ammonia can be converted to nitrite, which is toxic at high concentrations. Nitrite can be transformed into nitrate, which, even at high concentrations, does not interfere with cultivation. Nitrite concentrations up to 1 mg/L and nitrate up to 10 mg/L are considered adequate (BRASIL, 2005).

The P concentrations are in disagreement with the CONAMA resolution (BRASIL, 2005), which determines up to 0.05 mg L^{-1} in water for fish farming. High levels can increase the risk of eutrophication. To improve the effectiveness of water reuse in fish farming, producers must select quality feeds that do not contain excess N and P (MARQUES et al., 2018).

Elevated chloride levels can affect the ecosystem, altering reproduction rates and causing species mortality. When entering the water table, it can interfere with plant respiration and the quality of drinking water (ASCHE et al., 2013). In this study, chloride levels are within the permitted range, as per CONAMA resolution (BRASIL, 2005).

The Fe content increased in the effluents compared to the water from the supply channel. The rates in the T2 and T3 properties are above the recommended; however, the concentration of Fe in soils and water is not a factor of concern as long as the pH correction, when necessary, is prioritized (BOYD, 2016).

Understanding the dynamics of the effluent when applied to the soil is essential to promote its reuse. The average content of sand, silt and clay allowed the classification of the texture in loamy loam up to a layer of 20 cm depth (sand 49%, silt 22% and clay 29%). Table 3 presents the results of soil porosity in the evaluated areas.

Table 3: Mean and standard deviation of total porosity (TP), microporosity (MI), macroporosity (MA) and aeration porosity (AP) of soil under effluent from fish farming in western Bahia.

Treatments	TP ($m^3\ m^{-3}$)	MI ($m^3\ m^{-3}$)	MA ($m^3\ m^{-3}$)	AP ($m^3\ m^{-3}$)
		0.0 - 0.05 m		
0 year (T1)	0.46 ± 0.02 a	0.43 ± 0.02 a	0.05 ± 0.02 b	0.20 ± 0.01 b
5 years (T2)	0.45 ± 0.02 a	0.35 ± 0.02 b	0.08 ± 0.03 a	0.31 ± 0.03 a
20 years (T3)	0.30 ± 0.04 b	0.27 ± 0.03 c	0.03 ± 0.02 c	0.21 ± 0.04 b
	0.05 - 0.10 m			
0 year (T1)	0.43 ± 0.01 a	0.39 ± 0.02 a	0.04 ± 0.02 a	0.22 ± 0.02 b
5 years (T2)	0.41 ± 0.01 a	0.35 ± 0.01 a	0.05 ± 0.01 a	0.26 ± 0.01 a
20 years (T3)	0.32 ± 0.02 b	0.27 ± 0.01 b	0.03 ± 0.03 a	0.22 ± 0.02 b
	0.10 - 0.20 m			
0 year (T1)	0.43 ± 0.01 a	0.41 ± 0.01 a	0.04 ± 0.01 a	0.18 ± 0.02 b
5 years (T2)	0.41 ± 0.01 a	0.36 ± 0.02 b	0.05 ± 0.02 a	0.22 ± 0.02 a
20 years (T3)	0.28 ± 0.04 b	0.27 ± 0.01 c	0.04 ± 0.02 a	0.21 ± 0.02 a

Means followed by the same lowercase letter in the columns within each parameter and evaluated soil layer do not differ by Duncan's test at 5%. T1: property with 0 years of fish farming activity; T2: property with fish farming activity for 5 years; T3: property with fish farming activity for 20 years.

In the evaluated layers, the TP values did not differ between treatments T1 and T2, which were statistically higher than T3. There was a decrease in the MI related to the longer period of effluent reception, while the MA showed significant differences only in the layer from 0.00 to 0.05 m. Despite the changes in AP, the values are in agreement with the established critical limit for the development of most crops.

The reduction of pores, mainly after 20 years of application of the effluent in the soil, can be an indication of compaction. Compaction results from human activities and animal trampling, causing reduced porosity and increased Bd (SCHAEFFER et al., 2021). There was an increase in Bd in the layer from 0.05 m to 0.10 m in treatment T3 when compared to T1 and T2. The reduction of the volumetric water content is also characteristic of a compacted soil. The height of the stored water depth also presented a significantly different reduction in all the evaluated layers in the soil under T3 when compared to T1 and T2 (Table 4).

The results indicate higher values of TOC in the layer from 0.00 to 0.05 m and a decrease with depth in the three evaluated areas. Similar to what was observed by Costa Júnior et al. (2011) they obtained higher levels of TOC in the surface layer in studies of cerrado areas. According to the authors, this result is justified due to the greater contribution of material in the light fraction free of carbon in the surface layer of these areas. In addition, TOC values were lower in properties with longer effluent irrigation times.

Indicators are used to assess soil quality, and pH has been used to demonstrate soil sorption conditions (SILVA et al., 2020). Due to its buffering power, the pH of irrigation water does not significantly influence the pH of the soil. There was no significant change between T1 and T2 and between T2 and T3 in this study. Changes are observed between T1 and T3.

Table 4: Mean and standard deviation of bulk density (BD), height of water depth stored in the soil (h), total organic carbon (TOC) and pH of properties that received effluent from fish farming in western Bahia.

Treatments	BD (g cm^3)	h (mm)	TOC (g kg^{-1})	pH ($CaCl_2$)
		0.0 - 0.05 m		
0 year (T1)	1.48 ± 0.02 b	1.91 ± 0.01 a	19.87 ± 1.80 a	7.03 ± 0.07 a
5 years (T2)	1.54 ± 0.01 ab	1.17 ± 0.01 b	13.9 ± 1.08 b	6.94 ± 0.08 ab
20 years (T3)	1.60 ± 0.01 a	0.81 ± 0.02 c	7.88 ± 1.02 c	6.30 ± 0.20 b
		0.05 - 0.10 m		
0 year (T1)	1.55 ± 0.01 b	1.76 ± 0.01 a	16.54 ± 1.84 a	6.75 ± 0.09 a
5 years (T2)	1.47 ± 0.02 c	1.43 ± 0.01 b	12.22 ± 1.21 b	6.76 ± 0.07 ab
20 years (T3)	1.64 ± 0.04 a	0.59 ± 0.01 c	6.12 ± 1.08 c	6.13 ± 0.16 b
		0.10 - 0.20 m		
0 year (T1)	1.52 ± 0.02 b	3.83 ± 0.01 a	13.59 ± 1.76 a	6.97 ± 0.13 a
5 years (T2)	1.55 ± 0.02 b	2.91 ± 0.01 b	11.3 ± 1.04 b	6.88 ± 0.05 ab
20 years (T3)	1.71 ± 0.01 a	1.23 ± 0.01 c	4.19 ± 0.98 c	6.13 ± 0.15 b

Means followed by the same lowercase letter in the columns within each parameter and evaluated soil layer do not differ by Duncan's test at 5%. T1: property with 0 years of fish farming activity; T2: property with fish farming activity for 5 years; T3: property with fish farming activity for 20 years.

At high concentrations, Na can harm the soil structure by favoring the dispersion of mineral particles, and it can displace Ca and Mg into the soil solution, making them susceptible to leaching (MUSA et al., 2020). The time of irrigation with effluent may have influenced the decrease in Na and Ca observed in T3. Omeir et al. (2019) observed a decrease in Ca in basil and purslane irrigated with fish farm effluent water. In relation to Mg, in this study, there was an increase in the T2 property, indicating that in up to 5 years, the effluent positively influences its concentration; however, over long periods, Mg levels tend to decrease. Potential acidity showed no significant difference between T1 and T2 and did not differ between T2 and T3. This behavior was repeated at both evaluated depths. When soil acidity increases, soil fertility is affected (SÁTIRO et al., 2020) (Table 5).

Table 2: Mean and standard deviation of sodium (Na), calcium (Ca) magnesium (Mg) and potential acidity (H+Al) from farms that received fish farm effluent in western Bahia.

Treatments	Na (mmolc dm^{-3})	Ca (mmolc dm^{-3})	Mg (mmolc dm^{-3})	H+Al (mmolc dm^{-3})
		0.0 - 0.05 m		
0 year (T1)	0.42 ± 0.02 a	59.63 ± 5.23 a	7.70 ± 2.31 b	6.50 ± 1.18 b
5 years (T2)	0.39 ± 0.04 a	52.99 ± 4.85 a	12.43 ± 1.35 a	7.67 ± 1.32 ab
20 years (T3)	0.28 ± 0.01 b	31.68 ± 3.12 b	6.24 ± 1.74 b	8.83 ± 0.87 a
		0.05 - 0.10 m		
0 year (T1)	0.37 ± 0.02 a	55.83 ± 3.24 a	7.06 ± 2.02 b	7.55 ± 1.65 b
5 years (T2)	0.35 ± 0.04 a	51.03 ± 4.85 b	9.61 ± 0.74 a	8.00 ± 1.00 ab
20 years (T3)	0.23 ± 0.01 b	26.31 ± 6.12 c	5.50 ± 1.73 c	11.00 ± 1.92 a
		0.10 - 0.20 m		
0 year (T1)	0.43 ± 0.03 a	55.16 ± 5.99 a	6.82 ± 1.91 b	6.05 ± 5.37 b
5 years (T2)	0.41 ± 0.04 a	52.55 ± 3.48 b	9.30 ± 0.82 a	8.51 ± 7.87 ab
20 years (T3)	0.28 ± 0.02 b	27.01 ± 3.41 c	4.25 ± 0.41 c	11.05 ± 9.37 a

Means followed by the same lowercase letter in the columns within each parameter and evaluated soil layer do not differ by Duncan's test at 5%. T1: property with 0 years of fish farming activity; T2: property with fish farming activity for 5 years; T3: property with fish farming activity for 20 years.

The K concentrations can vary depending on the amount and composition of the applied effluent, the plant's assimilation mechanism and the type of soil (SÁTIRO et al., 2020). Irrigation with fish farming effluent was not able to increase the absolute value of the concentrations of K in the soil, showing a reduction of the nutrient with increasing depth and with the time of application of the effluent (Table 6). Silva et al.

(2018), when characterizing the chemical attributes of the soil before and after the application of fish farming effluent in corn and beans noticed a decrease in K, in contrast to the P values that increased.

Table 6: Mean and standard deviation of potassium (K), phosphorus (P_{mel}) extracted by the Mehlich method, remaining phosphorus (P_{rem}) and sulfur (S) of properties that received effluent from fish farming in western Bahia.

Treatments	K (mmolc dm^{-3})	P_{mel} (mg dm^{-3})	P_{mel} (mg dm^{-3})	S (mg dm^{-3})
		0.0 - 0.05 m		
0 year (T1)	5.24 ± 0.25 ab	12.20 ± 3.48 c	20.92 ± 1.46 c	6.83 ± 0.95 a
5 years (T2)	5.65 ± 0.33 a	19.63 ± 9.22 b	26.90 ± 2.22 b	6.35 ± 0.99 a
20 years (T3)	3.84 ± 0.99 b	30.28 ± 4.99 a	52.43 ± 1.79 a	4.42 ± 0.36 b
		0.05 - 0.10 m		
0 year (T1)	4.91 ± 0.28 a	9.33 ± 3.06 c	19.07 ± 1.95 c	9.47 ± 0.69 a
5 years (T2)	4.27 ± 1.14 ab	11.06 ± 1.66 b	22.10 ± 0.68 b	8.02 ± 0.41 b
20 years (T3)	3.21 ± 0.72 b	17.66 ± 5.92 a	48.60 ± 2.67 a	5.26 ± 0.28 c
		0.10 - 0.20 m		
0 year (T1)	4.65 ± 0.45 a	6.65 ± 1.83 b	17.50 ± 1.87 c	11.47 ± 1.44 a
5 years (T2)	3.06 ± 0.36 ab	9.90 ± 1.92 a	20.89 ± 0.91 b	9.75 ± 0.37 b
20 years (T3)	2.54 ± 0.91 b	8.24 ± 2.19 a	48.09 ± 2.60 a	6.60 ± 0.82 c

Means followed by the same lowercase letter in the columns within each parameter and evaluated soil layer do not differ by Duncan's test at 5%. T1: property with 0 years of fish farming activity; T2: property with fish farming activity for 5 years; T3: property with fish farming activity for 20 years.

The P values obtained in the soil of the T3 property increased with the effluent application time. P is a key element for productivity in agriculture, and soils rich in this nutrient potentially reduce the costs of commercial fertilizers (PREZOTTI et al., 2013; SÁTIRO et al., 2020).

Due to its ease of being leached in the form of sulfate, S has its content easily changed due to soil management. This justifies the decrease in its content in relation to the period of application of the effluent in T3. Prezotti et al. (2013) state that S concentrations are higher in the lower layers. This was observed in the properties evaluated, with higher values in the 0.10-0.20 m layer. Silva et al. (2018) observed a decrease in S values with the use of fish farm effluent to irrigate corn and beans.

The B content increased in T2 and decreased in T3 when compared to T1 (Table 7). Silva et al. (2017) when evaluating the effect of fish farming effluent on seedling production found similar results. The decrease in B, Cu and Mn values with time is due to leaching in soils with little organic matter. Sandy soils have lower Cu and Mn contents than clayey soils (PREZOTTI et al., 2013), a behavior that may justify the results found.

Table 7: Mean and standard deviation of boron (B), copper (Cu), iron (Fe) and manganese (Mn) from farms that received fish farm effluent in western Bahia.

Treatments	B (mg dm^{-3})	Cu (mg dm^{-3})	Fe (mg dm^{-3})	Mn (mg dm^{-3})
		0.0 - 0.05 m		
0 year (T1)	0.60 ± 0.09 b	3.24 ± 0.40 a	116.21 ± 29.91 a	47.82 ± 6.04 b
5 years (T2)	0.66 ± 0.11 a	3.01 ± 0.09 a	74.23 ± 14.25 b	51.55 ± 3.98 a
20 years (T3)	0.51 ± 0.08 b	1.00 ± 0.08 b	34.90 ± 6.21 c	33.26 ± 5.88 c
		0.05 - 0.10 m		
0 year (T1)	0.45 ± 0.03 b	3.00 ± 0.23 a	120.80 ± 31.47 a	43.60 ± 2.80 b
5 years (T2)	0.55 ± 0.09 a	2.92 ± 0.05 a	88.92 ± 9.80 b	45.02 ± 4.06 a
20 years (T3)	0.40 ± 0.05 b	0.99 ± 0.10 b	40.70 ± 8.69 c	30.71 ± 6.34 c
		0.10 - 0.20 m		
0 year (T1)	0.39 ± 0.03 b	2.98 ± 0.23 a	144.63 ± 28.03 a	36.94 ± 1.95 b
5 years (T2)	0.49 ± 0.10 a	2.85 ± 0.12 a	93.56 ± 10.25 b	38.30 ± 2.43 a
20 years (T3)	0.28 ± 0.06 c	0.90 ± 0.06 b	42.14 ± 11.76 c	23.89 ± 4.03 c

Means followed by the same lowercase letter in the columns within each parameter and evaluated soil layer do not differ by Duncan's test at 5%. T1: property with 0 years of fish farming activity; T2: property with fish farming activity for 5 years; T3: property with fish farming activity for 20 years.

The Zn values were higher at T2 and lower at T3 than at T1, and the values also tended to decrease with depth. On the other hand, Fe values were lower in properties that received effluents (Table 8). Silva et al. (2018) observed a reduction in Fe values in the soil under the application of fish farm effluent.

Table 8: Mean and standard deviation of zinc (Zn), bases sum (SB), cation exchange capacity (CEC$_{pH7}$) and percentage of bases saturation (V%) from properties that received fish farming effluent in western Bahia.

Treatments	Zn (mg dm^{-3})	SB (mmolc dm^{-3})	CEC$_{pH7}$ (mmolc dm^{-3})	V%
		0.0 - 0.05 m		
0 year (T1)	2.62 ± 0.66 b	74.65 ± 5.39 a	81.15 ± 4.22 a	91.91 ± 2.22 a
5 years (T2)	3.95 ± 0.14 a	72.57 ± 4.47 a	80.24 ± 4.19 a	90.42 ± 1.75 a
20 years (T3)	1.89 ± 0.24 c	43.67 ± 6.53 b	52.51 ± 5.98 b	82.90 ± 3.06 b
		0.05 - 0.10 m		
0 year (T1)	1.92 ± 0.48 b	70.31 ± 6.51 a	77.82 ± 5.16 a	90.24 ± 2.55 a
5 years (T2)	3.25 ± 0.37 a	65.25 ± 1.44 b	73.25 ± 2.26 b	89.10 ± 1.06 ab
20 years (T3)	1.72 ± 0.33 b	38.41 ± 7.57 c	49.41 ± 6.49 c	77.22 ± 5.64 b
		0.10 - 0.20 m		
0 year (T1)	1.68 ± 0.48 b	67.32 ± 8.03 a	73.82 ± 6.77 a	90.99 ± 2.92 a
5 years (T2)	2.81 ± 0.19 a	65.12 ± 2.98 a	73.62 ± 3.41 a	88.47 ± 1.12 b
20 years (T3)	1.51 ± 0.49 b	33.95 ± 2.76 b	45.28 ± 2.52 b	75.04 ± 5.25 c

Means followed by the same lowercase letter in the columns within each parameter and evaluated soil layer do not differ by Duncan's test at 5%. T1: property with 0 years of fish farming activity; T2: property with fish farming activity for 5 years; T3: property with fish farming activity for 20 years.

SB results from the sum of soil bases, such as Ca, Mg, K and Na (Teixeira et al., 2017), and is considered an indicator of chemical fertility. The SB values were reduced in the evaluated layers as the effluent was applied longer.

The SB is used in CEC and V% calculations, which together indicate soil fertility. CEC is the amount of cations that the soil can retain and is an important variable in the assessment of soil quality, since many nutrients used by plants and microorganisms are incorporated in the ionic form (SILVA et al., 2020). The greater amount of Al^{3+} and H^{+} and the presence of Na^{+} can reduce the negative charges of the soil, which are essential for the adsorption of bases such as K, Ca and Mg. T3 showed a greater decrease in CEC in relation to the others.

Bases saturation expresses the percentage of the CEC occupied by bases. In this study, V% was lower in properties that received effluent for a longer time, and values were above 50%, called eutrophic, with high fertility (SILVA et al., 2020; PREZOTTI et al., 2013). Such results are superior to those observed by Silva et al. (2018) when evaluating a soil irrigated with fish farm effluent.

Clay soils or soils with a high content of organic matter generally present high CEC, in contrast to sandy soils. In this sense, as determined in the granulometric fractions, the soil in properties T1 and T2 with clay texture and T3 with sandy texture can justify the CEC values obtained. Soils with CEC greater than 10 cmolc dm^{-3} have greater buffering power, requiring high amounts of limestone to change their PH (PREZOTTI et al., 2013).

To balance cations, the addition of nutrients is necessary to provide adequate Ca, Mg and K to the soil and plants. This balance must consider the possibility of a competitive ionic effect between the bases that interfere with the absorption of nutrients by the plant (WACAL et al., 2019).

The results point to the need for adequate management of fish farming effluent, from the monitoring of the water quality of the ponds to the control of exchange rates, population density and feeding. In addition, the management of the soil that receives the fluent also deserves attention to avoid compaction and/or leaching processes that interfere with the quality of this soil and possibly its sustainable use in fish farming-agriculture integration.

CONCLUSIONS

Regarding the characterization of the water, it is concluded that the water from fish farming has high turbidity and ammoniacal nitrogen outside the appropriate reference values.

Phosphorus values were increased both in water from the supply channel and in fish farming water. Despite this, the phosphorus content is in compliance for effluents.

The results reveal a decrease in porosity, an increase in density, and a decrease in the height of the stored water layer, micronutrients and macronutrients. The observed increase in phosphorus and decrease in sulfur are important for soil productivity.

It is concluded that to encourage the use of fish farming effluent from areas for irrigation, it is necessary to carry out appropriate management of both the effluent water and the soil.

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