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EFFLUENT QUALITY IN A FAMILY BIOWATER SYSTEM FOR AGRICULTURAL REUSE IN THE BAIXO JAGUARIBE REGION – CEARÁ

QUALIDADE DO EFLUENTE EM SISTEMA BIOÁGUA FAMILIAR PARA REÚSO AGRÍCOLA, REGIÃO DO BAIXO JAGUARIBE – CE

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ABSTRACT: The reuse of water has been an alternative for several sectors of the economy, which is stimulated mainly due to the Law nº 9.433, 01/08/1997, which established the National Policy on Water Resources. This study aimed at evaluating the quality of gray water in a Family Biowater System for agricultural reuse in the Baixo Jaguaribe region in CE, Brazil. The effluent samples were collected from April 2018 to March 2020, and the following physicochemical parameters were analyzed: Electrical Conductivity (EC), Chlorides (Cl), Sodium (Na) and Total Dissolved Solids (TDS) at the Environmental Sanitation Laboratory – LABOSAM of the IFCE Limoeiro do Norte Campus. The gray waters analyzed presented quality in relation to salinity ranging from good to medium, high and very high and were classified as C1; C2; C3 and C4, according to the methodology proposed by Richards (1954). The waters analyzed in P2 reuse tank showed higher values, and it was noted that a greater attention in relation to their use in irrigation is required; in P1 fat box, the waters were of better quality. It is suggested that for reuse in irrigation, the drip irrigation system should be used in order to prevent water with high salinity from causing toxicity in crops via foliar, when irrigated by conventional aspersion.

Keywords: *Salinity, Irrigation, Family Biowater, Reuse.*

RESUMO: O reúso de água vem sendo uma alternativa para vários setores da economia que é estimulado principalmente devido à LEI nº 9.433, 08/01/1997 que instituiu a Política Nacional de Recursos Hídricos. Este trabalho objetivou avaliar a qualidade das águas cinza em Sistema Bioágua Familiar para reúso agrícola na região do Baixo Jaguaribe – CE. As amostras dos efluentes foram coletadas do período de abr/2018 a mar/2020, sendo analisados os parâmetros físico-químicos: Condutividade Elétrica (CE), Cloretos (Cl), Sódio (Na) e Sólidos Totais Dissolvidos (STD) no Laboratório de Saneamento Ambiental – LABOSAM do IFCE Campus Limoeiro do Norte. As águas cinzas analisadas apresentaram qualidade com relação à salinidade variando de boa a média, alta e muito alta e foram classificadas como C1; C2; C3 e C4, conforme metodologia proposta por Richards (1954). As águas analisadas em P2 tanque de reúso, apresentaram valores mais elevados constatando-se que as mesmas deverão ter uma maior atenção em relação ao seu uso na irrigação, já em P1 caixa de gordura, as águas se mostraram de melhor qualidade. Sugere-se que para reúso em irrigação seja utilizado o sistema de irrigação localizada por gotejamento para evitar que águas com salinidades elevadas causem toxicidades nas culturas via foliar, quando irrigadas por aspersão convencional.

Palavras-chave: *Salinidade, Irrigação, Bioágua Familiar, Reúso.*

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INTRODUCTION

Water is a renewable natural resource essential for animal and plant life, constituting a fundamental factor in food production. Irrigated agriculture depends on both the quantity and the quality of water, with quality being one of the most important factors over a long period of time in the future. The quality of water for irrigation purposes varies significantly depending on the type and on the quantity of salts dissolved in it (AYERS; WESTCOT, 1999).

Saline waters used in irrigation can pose a risk to agricultural crop production. The effects of salinity on plants are due to salinity or sodicity, but usually both are involved. The presence of salts in the soil solution results in a decrease in the external water potential, as it negatively affects the absorption of water by the roots, causing physical effects. Specific ions can also cause toxic and nutritional effects. In certain cases, saline waters alter the physical and chemical conditions that did not initially exist in the soil, in proportions that hinder the growth and development of most crops (LAUCHLI; EPSTEIN, 1990).

Water reuse is becoming increasingly necessary, as our freshwater reserves must be preserved. According to the United Nations, it is estimated that global water consumption will increase by 20% to 30% by 2050 (FUSATI, 2021). Water reuse helps prevent waste by saving potable water, reducing watercourse pollution, and bringing cost savings for large companies, as water can be reused in manufacturing processes and more.

According to the National Water Agency (2003) - ANA, in Brazilian Portuguese, approximately 40% of treated water is wasted in Brazil. For this reason, among many others, water reuse is an excellent choice for companies and individuals who benefit from it. Water reuse has various purposes and can be practiced in urban, agricultural, and forestry settings, as well as for environmental purposes, aquaculture, animal husbandry, and more. It is worth noting that countries such as the United States, Japan, Israel, and Australia already utilize water reuse and make great use of this vital resource (CICLOJR, 2020).

Water reuse has been an alternative for various sectors of the economy, mainly stimulated by the Water Resources Law and the scarcity present in the Northeast region of Brazil, specifically in the Baixo Jaguaribe region, in Ceará, in the municipalities of Potiretama and Tabuleiro do Norte.

Water scarcity is a reality in these municipalities. However, the implementation of water reuse systems with the social technologies of Family Biowater implies significant environmental benefits only if they have technical and economic viability in the treatment and reuse of the liquid effluents generated by Family Biowater, allowing for a reduction in the discharge of sewage into water bodies. According to the Brazilian Semiarid Articulation (2022) - ASA, in Brazilian Portuguese, a technology is considered social when, in addition to providing technical means for performing a specific function or task, it acts to promote greater social interaction and transformation that is essentially inclusive, reflecting the ideologically heterogeneous set of social actors involved in the production and work process. These technologies are characterized by being low-cost, simple, practical, and meeting the demands of the most vulnerable class in society.

In this sense, the rational exploitation of all the potentialities of the semi-arid region of Baixo Jaguaribe, including grain production, irrigated fruit farming, and others, the existence of abundant labor, entrepreneurial capacity of the producers, and the associative mobilization of communities are factors which attract the implementation of social technologies that favor the reuse of domestic effluents. Different types of wastewater are generated within a household, and greywater represents the other household effluents that are generally produced from the washing of food, dishes, and clothes, as well as baths and other personal hygiene activities (TILLEY et al., 2014). In this way, Family Biowater is another social technology developed to improve the lives of communities and rural families, ensuring greater food security, environmental protection, supplementary family income, contribution to efficient water management, and the revival of agroecological practices based on the principles of coexistence with the semiarid region.

The importance of water reuse is related to avoiding the waste of effluent generated by domestic activities for non-potable purposes. However, greywater is considered an alternative water source, and in the context of sustainable water use, the reuse of treated greywater emerges as an action that contributes to the conservation of water resources.

Family Biowater is highly efficient in agricultural management and can be used for the cultivation of vegetables as well as sweet potatoes, cassava, and fruits. The advantages of this system are that, in addition to addressing a pollution problem through greywater control measures, it has low implementation and maintenance costs (BIOÁGUA FAMILIAR, 2012). The purpose of this research was to assess the quality of the effluent generated in the Family Biowater system in the municipalities of Potiretama and Tabuleiro do Norte, in the Baixo Jaguaribe region of Ceará. This system represents an alternative for the reuse of greywater for non-potable purposes in agricultural use.

MATERIAL AND METHODS

Study area characterization

The study was conducted in the agricultural backyard areas cultivated with water from clothes washing and kitchen sinks in the municipalities of Potiretama and Tabuleiro do Norte, located in the Baixo Jaguaribe region in the state of Ceará.

The study area is located in a region classified as hot and semi-arid, with temperatures above 18°C in the coldest month (BSW'h'), according to the Köppen classification (1918).

The region has two well-defined seasons: a dry season, lasting around seven to eight months (from July to December), and a rainy season, which rarely exceeds five months. The relative humidity ranges from 82% along the coast to less than 70% in the countryside. Table 1 shows the geographical coordinates and altitude of the city headquarters of the respective municipalities where the effluent samples were collected.

Table 1. Geographic coordinates and altitude of the municipalities' city headquarters - Ceará.

Municipalities	*Geographic Coordinates*		**Altitude of the city headquarters (m)**
	Latitude	**Longitude**	
Potiretama	5° 43’ 26” S	38° 09’ 22” W	133,0
Tabuleiro do Norte	5° 14’ 48” S	38° 07’ 50” W	39,7

Source: IPECE (2002).

The collections

The collections were carried out in the municipalities of Potiretama and Tabuleiro do Norte, from April 2018 to March 2020. A total of forty-six effluent samples were collected, with twenty-three samples representing P1 (fat box) and twenty-three representing P2 (reuse tank) (Table 2).

The samples were collected following the APHA methodology (2017) and subsequently stored in a cooler with ice until their arrival at the laboratory

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Table 2. Identification of the sampling points for effluent samples from Family Biowater, in the municipalities of Potiretama and Tabuleiro do Norte, Baixo Jaguaribe region - Ceará, from April 2018 to March 2020.

Sample identification	
1.P_1 fat box – Ant[a]. Sales, Potiretama (04/04/18)	1.P_2 reuse tank – Ant[a]. Sales, Potiretama (04/04/18)
2.P_1 fat box – Glautemberg, Potiretama (04/04/18)	2.P_2 reuse tank – Glautemberg, Potiretama (04/04/18)
3.P_1 fat box – Lucivânia, Tab. do Norte (04/04/18)	3.P_2 reuse tank – Lucivânia, Tab. do Norte (04/04/18)
4.P_1 fat box – Eliete, Tab. do Norte (04/04/18)	4.P_2 reuse tank – Eliete, Tab. do Norte (04/04/18)
5.P_1 fat box – Júnior, Potiretama (08/05/18)	5.P_2 reuse tank – Júnior, Potiretama (08/05/18)
6.P_1 fat box – Patrícia, Potiretama (08/05/18)	6.P_2 reuse tank – Patrícia, Potiretama (08/05/18)
7.P_1 fat box - M. Rd[a], Potiretama (05/06/18)	7.P_2 reuse tank – M. Rd[a], Potiretama (05/06/18)
8.P_1 fat box - Ant[a]. Sales, Potiretama (05/06/18)	8.P_2 reuse tank – Ant[a]. Sales, Potiretama (05/06/18)
9.P_1 fat box – Glautemberg, Potiretama (05/06/18)	9.P_2 reuse tank – Glautemberg, Potiretama (05/06/18)
10.P_1 fat box – Eliete, Tab. do Norte (12/03/18)	10.P_2 reuse tank – Eliete, Tab. do Norte (12/03/18)
11.P_1 fat box – Lucivânia, Tab. do Norte (12/03/19)	11.P_2 reuse tank – Lucivânia, Tab.Norte (12/03/19)
12.P_1 fat box – Aldelice, Tab. do Norte (12/03/19)	12.P_2 reuse tank – Aldelice, Tab. do Norte (12/03/19)
13.P_1 fat box – Jairo, Potiretama (26/03/19)	13.P_2 reuse tank – Jairo, Potiretama (26/03/19)
14.P_1 fat box – Júnior, Potiretama (26/03/19)	14.P_2 reuse tank – Júnior, Potiretama (26/03/19)
15.P_1 fat box – M[a] Antônia, Potiretama (26/03/19)	15.P_2 reuse tank – M[a] Antônia, Potiretama (26/03/19)
16.P_1 fat box – Eliete, Tab. do Norte (04/11/19)	16.P_2 reuse tank – Eliete, Tab. do Norte (04/11/19)
17.P_1 fat box – Vânia, Tab. do Norte (04/11/19)	17.P_2 reuse tank – Vânia, Tab. do Norte (04/11/2019)
18.P_1 fat box – Jairo, Potiretama (27/11/19)	18.P_2 reuse tank – Jairo, Potiretama (27/11/19)
19.P_1 fat box – Júnior, Potiretama (27/11/19)	19.P_2 reuse tank – Júnior, Potiretama (27/11/19)
20.P_1 fat box – M[a] Antônia, Potiretama (27/11/19)	20.P_2 reuse tank – M[a] Antônia, Potiretama (27/11/19)
21.P_1 fat box – Potiretama (03/03/20)	21.P_2 reuse tank – Potiretama (03/03/20)
22.P_1 fat box – Potiretama (03/03/20)	22.P_2 reuse tank – Potiretama (03/03/20)
23.P_1 fat box – Potiretama (03/03/20)	23.P_2 reuse tank – Potiretama (03/03/20)

Source: prepared by the authors.

The samples came from the effluents generated by the Family Biowater System, which works based on the filtration of gray water by means of physical and biological impediment of the residues present in it. Thus, the system consists of a filter that contains two layers of organic material (humus and wood sawdust) and two layers of inorganic material (gravel and pebble), which must be covered to avoid sunlight. A reuse tank is also used to store the water coming from the filter. And finally, it comprises an irrigation system, which must be designed by a professional in the area of irrigation, recommending the use of dripping, so that there is no direct contact between the operator and the water, in addition to recommending the use of a pump and polyethylene hoses for dripping.

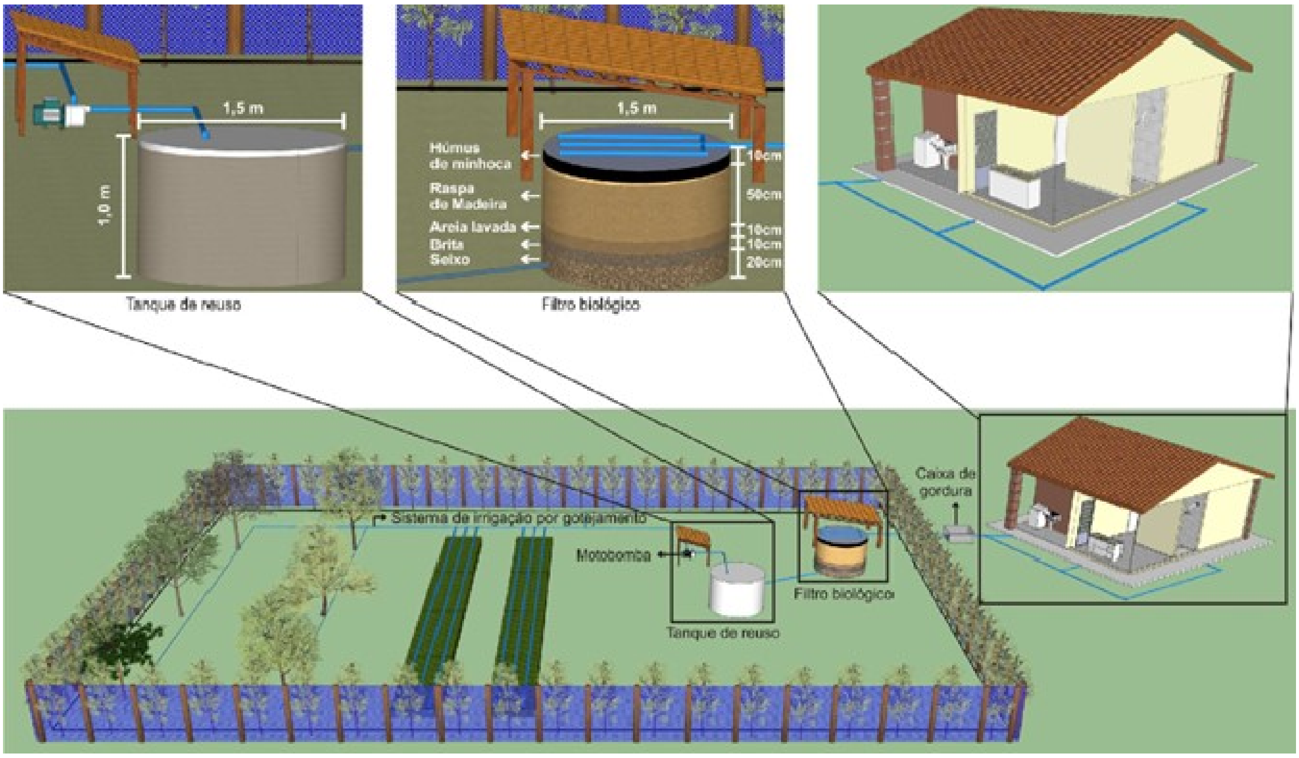

Figure 1. Layout of the Water Reuse System – Family Biowater.
Source: Family Biowater: Gray water reuse for food production. Proom Helder Câmara (2012).

The analyzes

The analyzes were carried out at the Laboratory of Environmental Sanitation - LABOSAM of the IFCE Limoeiro do Norte Campus, following the methodology of the APHA (2017), where the physicochemical parameters analyzed were: Electrical Conductivity (EC), Chlorides (Cl), Sodium (Na) and the Total Dissolved Solids (TDS), according to Table 3 below doses.

Table 3. Parameters for assessing water quality for irrigation purposes.

PARAMETER	SYMBOL	UNIT	METHOD APHA (2017)
Electric Conductivity	EC	dS m^{-1}	2510 B.
Sodium	Na^+	$mmol_c$ L^{-1}	3500 – Na B.
Chlorides	Cl^-	$mmol_c$ L^{-1}	4500 – Cl^- B.
Total Dissolved Solids	TDS	mg L^{-1}	2540 C.

Source: prepared by the authors.

Water intended for irrigation should be evaluated mainly under three aspects, which are considered fundamental in determining its agronomic quality, namely: Salinity, Sodicity and Toxicity by Specific Ions. As far as Salinity is concerned, Electrical Conductivity (EC) and/or Total Dissolved Solids (TDS) and Sodium Adsorption Ratio (SAR) are evaluated, according to Ayers and Westcot (1999).

The EC, which represents an indirect measure of the total concentration of soluble salts, is one of the main indicators of the classification and quality of water for irrigation (RICHARDS, 1954). The EC presents a direct relationship with TDS, and the fixed part of the total dissolved solids is considered as salinity (PORTO et al., 1991). Thus, excess TDS in water can cause changes in taste, corrosion problems and soil salinization.

In order to assess the quality of irrigation water, the most common classification proposed by Richards (1954) was used, in which four classes of salinity are adopted, because as the concentration of salts increases, the electrical conductivity also increases. The salinity levels are named C1, C2, C3 and C4, where C1 represents the low-salinity water class and C4 the very high salinity class. Richards (1954) also mentions that as for the risk of sodicity, the classification is made based on the threshold values of sodium adsorption ratio (SAR), which is also divided into four classes: S1, S2, S3 and S4, with S1 being water with low sodicity and S4 the water with very high sodicity (Table 4).

Table 4. Classification of irrigation water according to salinity risk.

Salinity Class	Richards (1954)	UCCC[1]	Salinity Risk	Ayers and Westcot (1991)	
	Range ECa[2] (dS m^{-1})			Range ECa[2] (dS m^{-1})	Salinity Problem
C_1	< 0,25	< 0,75	Low	< 0,7	none
C_2	0,25 – 0,75	0,75 – 1,50	Average	0,7 – 3,0	moderate
C_3	0,75 – 2,25	1,50 – 3,00	High	> 3,0	severe
C_4	> 2,25	> 3,00	Very high	-	-

[1]UCCC – University of California Committee of Consultant's (Source: Pizarro, 1985).
[2]ECa – Electrical Conductivity of irrigation water.

RESULTS AND DISCUSSION

Based on the tests carried out, Tables 5 and 6 show the results of the physicochemical analyzes: Electrical Conductivity (EC), Chlorides (Cl), Sodium (Na) and Total Dissolved Solids (TDS) of the Family Biowater effluents for the collection points, P1 fat box and P2 reuse tank, according to other sample identifications in the tables below.

Table 5. Physicochemical and microbiological characterization of the Family Biowater effluent in the municipalities of Potiretama and Tabuleiro do Norte, Baixo Jaguaribe region – Ceará, from April 2018 to March 2020 in P_1 fat box.

Identification of samples	EC µS cm^{-1}	Chlorides $mmol_c/L$ Cl^-	Sodium $mmol_c/L$ Na	TDS mg/L
1.P_1 fat box – Ant[a]. Sales, Potiretama (04/04/18)	598,80	2,31	4,23	389,22
2.P_1 fat box – Glautemberg, Potiretama (04/04/18)	424,20	1,95	5,20	275,73
3.P_1 fat box – Lucivânia, Tab. do Norte (04/04/18)	554,25	1,63	2,63	360,26
4.P_1 fat box – Eliete, Tab. do Norte (04/04/18)	474,05	2,05	7,16	308,13
5.P_1 fat box – Júnior, Potiretama (08/05/18)	301,55	8,11	1,74	196,01
6.P_1 fat box – Patrícia, Potiretama (08/05/18)	1345,00	7,46	11,85	874,25
7.P_1 fat box – M. Rd[a], Potiretama (05/06/18)	427,05	2,84	3,50	277,58
8.P_1 fat box - Ant[a]. Sales, Potiretama (05/06/18)	171,00	2,44	0,08	111,15

9.P_1 fat box – Glautemberg, Potiretama (05/06/18)	516,95	3,25	2,18	336,02
10.P_1 fat box – Eliete, Tab. do Norte (12/03/18)	256,50	0,26	7,71	166,73
11.P_1 fat box – Lucivânia, Tab. do Norte (12/03/19)	643,50	1,61	3,98	313,00
12.P_1 fat box – Aldelice, Tab. do Norte (12/03/19)	677,50	2,64	4,98	352,00
13.P_1 fat box – Jairo, Potiretama (26/03/19)	1000,50	5,09	6,02	1343,00
14.P_1 fat box – Júnior, Potiretama (26/03/19)	611,00	2,13	8,69	388,00
15.P_1 fat box – Mª Antônia, Potiretama (26/03/19)	737,00	3,09	5,25	397,15
16.P_1 fat box – Eliete, Tab. do Norte (04/11/19)	1336,00	10,70	4,72	1024,00
17.P_1 fat box – Vânia, Tab. do Norte (04/11/19)	1572,00	10,72	5,14	800,00
18.P_1 fat box – Jairo, Potiretama (27/11/19)	545,00	1,39	11,12	330,00
19.P_1 fat box – Júnior, Potiretama (27/11/19)	1297,00	1,38	6,27	1295,00
20.P_1 fat box – Mª Antônia, Potiretama (27/11/19)	1468,00	1,39	38,15	944,00
21.P_1 fat box – Potiretama (03/03/20)	1359,50	7,54	24,59	452,67
22.P_1 fat box – Potiretama (03/03/20)	797,00	2,35	16,47	533,33
23.P_1 fat box – Potiretama (03/03/20)	1358,00	6,02	14,79	444,00
Average	**803,10**	**3,84**	**8,54**	**517,88**
Standard deviation	**436,37**	**3,06**	**8,49**	**350,48**
Coefficient of variation	**54,3%**	**79,7%**	**99,4%**	**67,7%**
Nº. of sumples	**23**	**23**	**23**	**23**
Minimum value	**171,00**	**0,26**	**0,08**	**111,15**
Maximum value	**1572,00**	**10,72**	**38,15**	**1343,00**

Source: prepared by the authors.

Table 6. Physicochemical and microbiological characterization of the Family Biowater effluent in the municipalities of Potiretama and Tabuleiro do Norte, Baixo Jaguaribe region - Ceará, from April 2018 to March 2020 in the P_2 reuse tank.

Identification of samples	**EC µS cm^{-1}**	**Chlorides mmmol$_c$/L Cl$^-$**	**Sodium mmol$_c$/L Na**	**TDS mg/L**
1.P_2 reuse tank – Antª. Sales, Potiretama (04/04/18)	1044,00	2,39	8,76	678,60
2.P_2 reuse tank – Glautemberg, Potiretama (04/04/18)	953,70	2,39	8,86	619,91
3.P_2 reuse tank – Lucivânia, Tab. do Norte (04/04/18)	950,05	2,45	6,55	617,53
4.P_2 reuse tank – Eliete, Tab. do Norte (04/04/18)	1171,00	3,95	9,92	761,15
5.P_2 reuse tank – Júnior, Potiretama (08/05/18)	1139,50	7,79	9,02	740,68
6.P_2 reuse tank – Patrícia, Potiretama (08/05/18)	877,90	6,17	6,68	570,64
7.P_2 reuse tank - M. Rdª, Potiretama (05/06/18)	1645,50	9,91	24,03	1069,58
8.P_2 reuse tank - Antª. Sales, Potiretama (05/06/18)	1041,60	7,47	6,79	677,04
9.P_2 reuse tank – Glautemberg, Potiretama (05/06/18)	857,05	3,82	5,52	557,08
10.P_2 reuse tank – Eliete, Tab. do Norte (12/03/18)	1231,50	2,96	4,86	559,00
11.P_2 reuse tank – Lucivânia, Tab. do Norte (12/03/19)	2025,00	2,83	6,22	1070,00

12.P_2 reuse tank – Aldelice, Tab. do Norte (12/03/19)	1414,00	3,74	6,66	560,00
13.P_2 reuse tank – Jairo, Potiretama (26/03/19)	1942,00	6,25	10,19	764,00
14.P_2 reuse tank – Júnior, Potiretama (26/03/19)	1194,00	5,35	10,74	1262,30
15.P_2 reuse tank – Mª Antônia, Potiretama (26/03/19)	1580,00	6,18	7,54	776,10
16.P_2 reuse tank – Eliete, Tab. do Norte (04/11/19)	3600,00	6,17	9,21	1454,00
17.P_2 reuse tank – Vânia, Tab. do Norte (04/11/2019)	1508,50	13,65	9,55	1134,00
18.P_2 reuse tank – Jairo, Potiretama (27/11/19)	1332,00	0,62	22,34	1110,00
19.P_2 reuse tank – Júnior, Potiretama (27/11/19)	1539,50	0,35	34,86	1333,00
20.P_2 reuse tank – Mª Antônia, Potiretama (27/11/19)	1391,50	8,20	27,35	1083,00
21.P_2 reuse tank – Potiretama (03/03/20)	1375,00	8,22	22,52	726,67
22.P_2 reuse tank – Potiretama (03/03/20)	1080,00	3,91	17,24	482,00
23.P_2 reuse tank – Potiretama (03/03/20)	1193,50	4,84	15,00	631,33
Average	**1395,08**	**5,20**	**12,63**	**836,42**
Standard deviation	**572,62**	**3,11**	**8,15**	**285,49**
Coefficient of variation	**41,0%**	**59,9%**	**64,5%**	**34,1%**
Nº. of samples	**23**	**23**	**23**	**23**
Minimum value	**857,05**	**0,35**	**4,86**	**482,00**
Maximum value	**3600,00**	**13,65**	**34,86**	**1454,00**

Source: prepared by the authors.
*nd - not determined

Electrical Conductivity

From the data presented in Table 5 and Figure 2, it can be seen that the Electrical Conductivity for all points studied presented, in general, values ranging from 171.00 to 1572.00 µS cm-1, and these waters were classified in relation to the salt content, according to the methodology proposed by Richards (1954) as: C1 low salinity danger and C3 high salinity danger in 8.P1 fat box - Antª. Sales, Potiretama (05/06/18) and 17.P1 fat box – Vânia, Tab. do Norte (04/11/19), respectively, with the last value having a greater restriction on its use for irrigation.

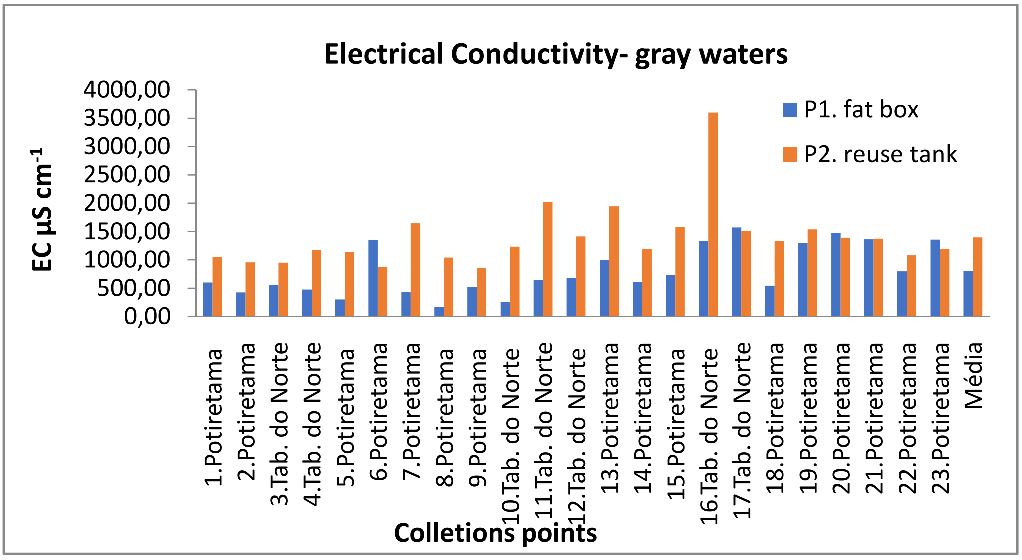

Figure2. Temporal variation of electrical conductivity in gray water from the Family Biowater System P_1 fat box and P_2 reuse tank, from April 2018 to March 2020, in the municipalities of Potiretama and Tabuleiro do Norte - CE.

From the data presented in Table 6 and in Figure 2, it can be seen that the electrical conductivity for all points studied presented, in general, values ranging from 857.05 to 3600.00 µS cm-1, and these waters were classified in relation to salt content, according to the methodology proposed by Richards (1954) as: C3 high salinity danger and C4 very high salinity danger in 9.P2 reuse tank – Glautemberg, Potiretama (05/06/18) and 16.P2 reused tank – Eliete, Tab. do Norte (04/11/19), respectively, and both values showed a greater restriction regarding its use for irrigation.

The average values of EC obtained at the points studied in P1 fat box and P2 reuse tank were 803.10 µS cm-1 and 1395.08 µS cm-1 respectively, classifying these waters in danger of high salinity for irrigation, according to the classification of Richards (1954) in Table 4, where the average EC values are in the range from 750 to 2250 µS cm-1, as well as other ranges of references are found in Table 4.

Therefore, these results require attention and care regarding its application in crops, as well as soil salinization. It is noteworthy that the water analyzed in P1 fat box had EC values lower than in P2 reuse tank, and this result requires attention and care regarding its application in cultures, as well as soil salinization.

This result was possibly due to the fact that water, when passing through the filtration system, acquired a higher concentration of salts through the organic compounds that are contained in the filter and thus contributed to its dissolution in water: organic compounds such as humus (manure) is not tanned, the manure is in the process of decomposition, releasing salts as well as the manure has the presence of urine and since it is salty, contributes to the increase of the salinity of the water as well as in the process of decomposition of the humus, humus age and quality.

Concerning the inorganic compounds in the layers of washed sand, gravel and pebbles, the effluent passing through the filter layers, may undergo alteration with the release of salts, causing an increase in salinity; however, this process is very slow, which can be inferred that does not contribute in the short term to the increase in salinity of the water. In general, water with this classification should be used in soils with medium to high hydraulic conductivity and leaching must be carried out to avoid salinization problems (RHOADES et al., 1992).

These results corroborate Silva et al. (2018), who while studying the efficiency of the biowater system in the treatment of gray water, obtained the average EC value in the reuse tank of 1041 µS cm-1, classifying it according to the danger of high salinity for irrigation, according to the classification of Richards (1954). Lopes et al. (2021), while analyzing gray water from Family Biowater in the semi-arid region of Paraíba, found an average EC value of 2640 µS cm-1 in the reuse tank. According to the World Health Organization (2006), water containing an EC from 700 to 3000 µS cm-1 presents a slight to moderate degree of restriction for irrigation, thus, the water in the reuse tank are within this range.

Chlorides

According to Ayers e Westcot (1991), chloride is easily displaced in the soil with irrigation water, although it is absorbed by the roots and translocated to the leaves, where it accumulates through the transpiration process. Necrosis and leaf burns are characteristic symptoms of chloride toxicity. In sensitive cultures, these symptoms are manifested when concentrations between 0.3% and 1% of chloride are reached, based on the dry weight of the leaves. The uptake of chloride by irrigated crops depends not only on the quality of the water, but also on the plant's ability to exclude it and its content in the soil, which is controlled with leaching.

In Table 5 and in Figure 3, it is observed that among the points under study, the lowest value of chloride ion was 0.26 mmolc L-1 in 10.P1 fat box – Eliete, Tab. do Norte (12/03/18) and the highest value was 10.72 mmolc L-1 in 17.P1 fat box – Vânia, Tab. do Norte (04/11/19). The average value obtained was 3.84 mmolc L-1, the standard deviation of 3.06 and the Coefficient of variation obtained was 79.7%, showing that there was a great temporal variation in the concentration of chlorides; however, there were important differences between the points studied.

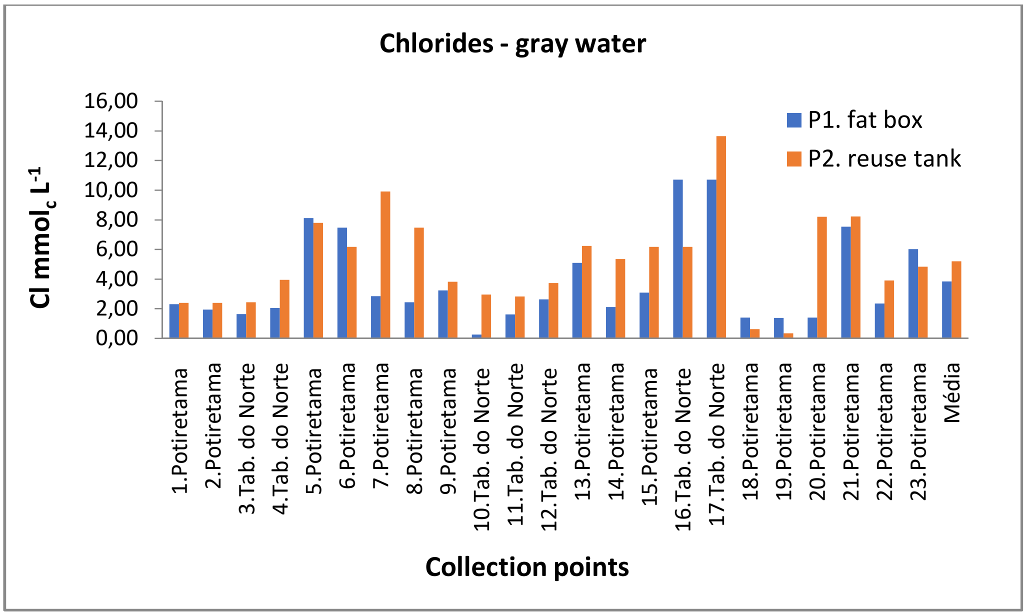

Figure 3. Temporal variation of Chlorides in gray water from the Family Biowater System P_1 fat box and P_2 reuse tank, from April 2018 to March 2020, in the municipalities of Potiretama and Tabuleiro do Norte - CE.

It is noteworthy that of the twenty-three samples analyzed, eight of them were restricted for use in irrigation, since according to Ayres e Westcot (1999), waters with chloride ion concentration values greater than 3.0 mmolc L-1 represent limitations regarding the use for irrigation; among these eight samples mentioned, seven of them presented a high degree of restriction for use in irrigation, especially if this water is irrigated by sprinkling because the concentrations of this ion in that location reach the limits of toxicity presented by Ayers e Westcot (1991), which are 5 to 10 mmolc L-1.

In Table 6 and Figure 3, it is observed that among the points studied, the lowest value of chloride ion was 0.35 mmolc L-1 in 19.P2 reuse tank – Júnior, Potiretama (11/27/19) and 13, 65 mmolc L-1 in 17.P2 reuse tank – Vânia, Tab. do Norte (04/11/2019). The average value obtained was 5.20 mmolc L-1 and, according to this value, the waters in the P2 reuse tank were restricted for use in irrigation, since, according to Ayres e Westcot (1999), waters with ion concentration values of chloride higher than 3.0 mmolc L-1 represent limitations regarding the use for irrigation, especially if the irrigation is by sprinkling, because in some samples analyzed in P2 reuse tank, the concentrations of this ion reached limits of toxicity presented by Ayers e Westcot (1991), which are 5 to 10 mmolc L-1. The standard deviation was 3.11 and the coefficient of variation obtained was 59.9%, showing that there was a great temporal variation in the chloride concentration, but important differences between the points studied.

The average values of chlorides found in P1 fat box and P2 reuse tank were 3.84 and 5.20 mmolc L-1, respectively, and the water in P2 reuse tank showed higher values than in P1 fat box. Since the chloride ion is highly soluble, therefore liable to be easily leached, it cannot accumulate in the soil; however, if irrigation occurs through sprinkling, problems of phytotoxicity will arise, which will be clearly noticeable through the appearance of burns in the leaves.

Significantly high concentrations of chlorides (37.9 mmolc L-1) were found by Santos et al. (2018) when analyzing the quality of the effluent from cleaning the swimming pool for reuse in landscape irrigation at the IFCE Campus Limoeiro do Norte - Ceará; this value reached the toxicity limits presented by Ayers e Westcot (1991),which means a special care is required when using this water for agricultural purposes, as this ion is directly related to the concentration of dissolved salts in the water. Arraes et al. (2007) found high values of chloride studying the Curu River hydrographic basin in Ceará; such values are explained by the fact that sewage and washing of clothes occur along the basin.

Sodium

The temporal variation of sodium ion concentration is shown in Table 5 and Figure 4. The average values of sodium found in P1 fat box (Table 5) and P2 reuse tank (Table 6) were 8.54 and 12.63 mmolc L-1, respectively, and the water in P2 reuse tank showed higher values than in P1 fat box; however, both have moderate restriction regarding their use in irrigation, because according to Ayres e Westcot (1999), when the sodium concentration is higher than 3.0 mmolc L-1, the salinity of this ion affects water availability for crops.

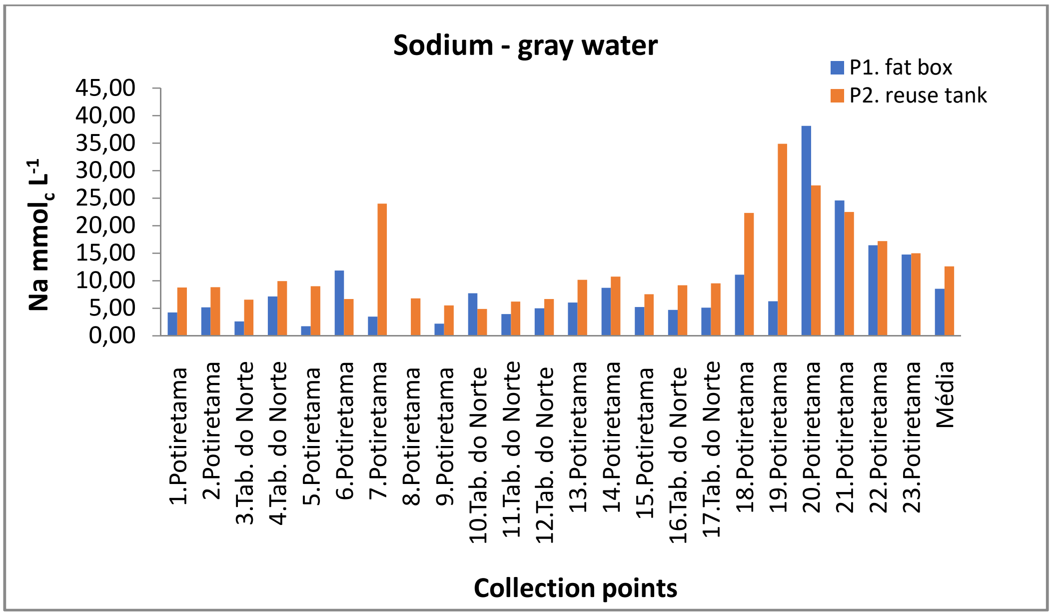

Figure 4. Sodium temporal variation in gray water from the Family Biowater System P_1 fat box and P_2 reuse tank, from April 2018 to March 2020, in the municipalities of Potiretama and Tabuleiro do Norte - CE.

However, for the studied waters, the concentration values of this ion varied between 0.08 mmolc L^{-1} in the 8.P_1 fat box - Ant[a]. Sales, Potiretama (06/05/18) and 38.15 mmolc L^{-1} in 20.P_1 fat box - Maria Antônia, Potiretama (11/27/19). The average value obtained was 8.54 mmolc L^{-1}, the standard deviation of 8.49 and the coefficient of variation obtained was 99.4%, showing that there was a high temporal variation in the concentration of this ion between the points studied. Among the twenty-three samples analyzed, only four (Table 5) did not present any risk of toxicity to the plants in the use of surface irrigation according to Ayres e Westcot (1999).

As for the other samples that obtained values greater than 3.0 mmolc L^{-1} of sodium, these nineteen samples represent, in terms of use for irrigation, moderate restriction (AYRES; WESTCOT, 1999), as sodium concentrations greater than 3.0 mmolc L^{-1} both affects water availability for crops and its toxicity is more difficult to diagnose than chloride and therefore can be clearly identified through water analysis. In contrast to symptoms of chloride toxicity which begin at the apex of leaves, typical sodium symptoms appear in the form of burns or necrosis along the edges, and sodium concentrations in leaves reach toxic levels after several days or weeks; the symptoms first appear on the older leaves and on their edges and, as they intensify, the necrosis progressively spreads in the intermural area to the center of the leaves. Among many sensitive crops are citrus, avocado, beans, among others.

The temporal variation of the sodium ion concentration is represented in Table 6 and Figure 4. For the studied samples, the sodium concentration values varied between 4.86 mmolc L^{-1} in the 10.P_2 reuse tank – Eliete, Tab. do Norte (03/12/18) and 34.86 mmolc L^{-1} in 19.P_2 reuse tank – Júnior, Potiretama (11/27/19).

The average value obtained was 12.63 mmolc L^{-1}, the standard deviation of 8.15 and the coefficient of variation obtained was 64.5%, which shows that there was less variation in the results than in P_1 fat box (which was 99.4%) and, therefore, a smaller temporal variation in the concentration of this ion between the points studied, but in P_2 reuse tank, the mean value obtained was higher than in P_1 fat box.

It is noteworthy that all samples analyzed in the P_2 reuse tank obtained values greater than 3.0 mmolc L^{-1} and therefore presented a moderate risk of toxicity for the plants when using surface irrigation, according to Ayres e Westcot (1999).The sodium values recorded in the study characterized a high concentration of sodium, indicating that it is necessary to be careful about the use of this water for irrigation, always trying to implant cultures adapted to these conditions. Irrigation with water of this quality would imply an input of approximately 208 kg of sodium per m^3 of water. In general, the water from the fat box expresses a lower degree of toxicity for surface irrigation than the water from the reuse tank. Silva et al. (2018), when studying the efficiency of the biowater system in the treatment of gray water, obtained an average sodium value of 8.59 mmolc L^{-1}; Lopes et al. (2021), when analyzing the gray water of Family Biowater in the semiarid region of Paraíba, found an average Na of 29.96 mmolc L^{-1} in the reuse tank, where both values are above 3.0 mmolc L^{-1}, presenting a moderate risk of toxicity to the plants in the use of surface irrigation (AYRES; WESTCOT, 1999). According to Batista et al. (1998), high levels of sodium can cause reduced crop development, reduced production due to nutritional problems and deterioration of soil structure.

It is worth mentioning that it was not possible to determine Calcium and Magnesium to obtain the calculation of the SAR - Sodium Adsorption Ratio, due to the samples having different colors and thus making it impossible to change the chemical reaction at the time of the titration due to the method adopted being the EDTA titrimetry for the determination of Calcium and Magnesium Hardness. For this, the samples would need a treatment to remove and/or soften their color or change the way of determination to AAS - Atomic Absorption Spectrophotometer.

Total Dissolved Solids – TDS

In Tables 5 and 6 and Figure 5, it can be seen that the average values of TDS were 517.88 mg L^{-1} and 836.42 mg L^{-1} in P_1 fat box and P_2 reuse tank, respectively

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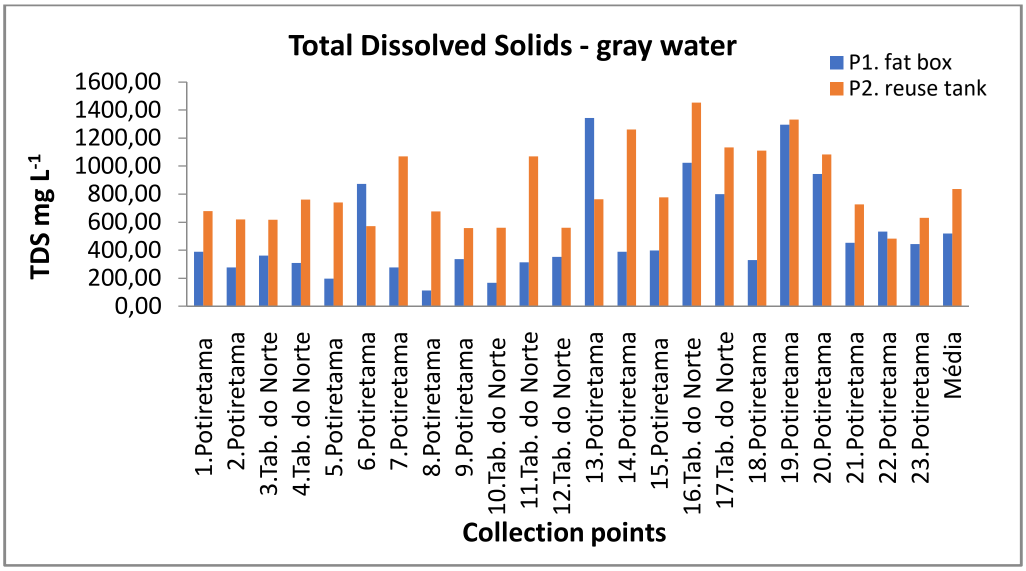

Figure 5. Temporal variation of Total Dissolved Solids - TDS in gray water from the Family Biowater System P_1 fat box and P_2 reuse tank, from April 2018 to March 2020, in the municipalities of Potiretama and Tabuleiro do Norte – CE.

In general, the waters in P_2 reuse tank showed TDS concentrations higher than those presented for P_1 fat box. These values differ from those found by Lopes et al. (2021) when analyzing gray water from Family Biowater in the semi-arid region of Paraíba: they found an average TDS value of 1.70 mg L^{-1} in the reuse tank, which is very different from the reality in this study in the semiarid climate in Ceará.

It is known that TDS is the set of all organic and inorganic substances contained in a liquid in molecular, ionized or microgranular forms, and this is a parameter of paramount importance for determining the quality of water, as it evaluates the total weight of mineral constituents present in the water.

Possibly, the increase in TDS values in the P_2 reuse tank is due to organic compounds in the layers of earthworm humus and wood sawdust, where the quality and age of the humus (manure) must be analyzed, where it may not have been completely tanned and since it is in the process of decomposition, it releases salts, it contains salt and thus, the effluent, when passing through the filter layers, undergoes alteration with the release of salts, causing an increase in salinity.

However, the ideal is that tests are carried out with other organic materials, as well as investigating whether the manure is tanned, what is the age of the manure, among others.

CONCLUSIONS

According to the results obtained in this work, it can be concluded that the gray water from the Family Biowater Systems analyzed in the region of Baixo Jaguaribe - CE presented salinity quality varying, regarding its use for irrigation, from good to medium, high and very high and they were classified as C_1; C_2; C_3 and C_4.

In general, the waters analyzed in P_2 reuse tank presented higher values in relation to the physicochemical characteristics; it was noted that they should have greater attention concerning their use in irrigation; however, the waters in P_1 fat box proved to be of better quality for use in irrigation.

It is important to highlight that the increase in salinity values in the P_2 reuse tank is possibly due to organic compounds in the layers of earthworm humus and wood sawdust, which causes an increase in salinity.

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