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Article - Environmental Sciences

Estuaries Environmental Monitoring Associated with Solar Salt Production in the Brazilian Semiarid

Rogério Taygra Vasconcelos Fernandes[1*]
http://orcid.org/0000-0002-2901-3986

Raimunda Thyciana Vasconcelos Fernandes[2]
https://orcid.org/0000-0002-8019-1227

Aruza Rayana Morais Pinto[3]
https://orcid.org/0000-0002-2776-222X

Jônnata Fernandes de Oliveira[4]
https://orcid.org/0000-0001-7325-435X

José Luís Costa Novaes[5]
https://orcid.org/0000-0003-0667-4279

[1]Universidade Federal Rural do Semi-Árido (UFERSA), Agrarian Sciences Center, Solar Salt Lab Research Group – SSB, Mossoró, RN, Brazil; [2,3]Equilíbrio Gerenciamento Ambiental, Mossoró, RN, Brazil; [4]Instituto Federal do Maranhão (IFMA), Carolina, MA, Brazil; [5]Universidade Federal Rural do Semi-Árido (UFERSA), Biological and Health Sciences Center, Mossoró, RN, Brazil.

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*Correspondence: rogerio.taygra@ufersa.edu.br; Tel.: (+55) 8498742-0141 (R.T.V.F.).

HIGHLIGHTS

- Solar saltwork production does not affect water quality.
- Salinity is not affected by salt production.
- The ions present in the estuary are not affected by salt production.
- The estuary is oligotrophic and is not affected by salt production.

Abstract: The salt is indispensable for several industrial sectors, and its production is associated with some natural conditions. These conditions result in productive areas often close to the estuary. Thus, the objective was to evaluate the estuaries environmental monitoring associated with solar salt production in the Brazilian semiarid. The study was developed in the area of influence of a solar saltwork, in the Conchas' river estuary, RN, where the quality of the water in the estuary was monitored for the non-productive and productive periods of the saltwork for 3 years. Thus, a collection site was established immediately in front of the saltwork discharge channel, and samples were collected monthly, at 30 cm depth, always during high tides, totaling 36 samples. For this, the following parameters were evaluated: salinity, pH, calcium, magnesium, dissolved oxygen, chlorophyll *a* and rainfall. Salinity was measured in the field with the aid of a portable refractometer. During the operational phase, the average salinity remained above 30.00, characterizing the environment as saline. The calcium and magnesium ions showed an average concentration of 440.00 mg/L and 1280.00 mg/L respectively, values that were according to the limits historically observed for a saline estuary in the analyzed region. The pH and dissolved oxygen were not influenced by the production period (7.93 and above 6.00mg/ L, respectively), while the concentration of chlorophyll *a* characterized the area as oligotrophic. The functioning of the analyzed solar saltwork did not cause significant changes in the water quality parameters of the estuary.

Keywords: chlorophyll *a*; pH; rainfall; salinity.

INTRODUCTION

Common salt, formed mainly by sodium chloride, is considered an indispensable element for various sectors of the food, chemical, metallurgical, agricultural and pharmaceutical industries, and is therefore a raw material for multiple economic activities. The most traditional method for the production of salt consists of solar evaporation, where the seawater is dammed in clay dikes, forming saline lagoons. These lagoons, or tanks, are exposed to the action of the sun and the wind until, gradually, by the action of gravity or through the use of motor-pumps, water with an average initial salinity of 35g/L circulates between the evaporator tanks, concentrators and crystallizes until the sodium chloride supersaturation point, between 260 and 280 g/L [1,2].

For the production of salt by solar evaporation to be technically feasible, some natural conditions need to be met, among which: proximity to salt water sources; stocks of flat areas with little permeable soil; low or concentrated annual rainfall in a few months of the year; and high insolation and evaporation rate [3]. These requirements mean that few places in the world are able to produce salt by evaporation on an industrial scale, resulting in the grouping of productive areas in small geographic regions.

In Brazil, a country that occupies the ninth position in the ranking of the largest salt producers in the world, more than 95% of the production takes place in an area less than 200 km², located on the Salt Coast, coast of the Northeast region [4]. Although the high saline productivity contributes to the socioeconomic development of the producing region, by using seawater as a raw material, and depending on specific climatic conditions, the salt flats are usually built on the margins of estuaries and bays in arid and semi-arid regions, it can generate negative environmental impacts on coastal ecosystems [5].

Among the severe impacts are the interruption of water courses, devastation of mangroves, salinization of areas productions, alteration of humidity in the region due to the increase in evaporation of solar saltwork, alteration of the marine and terrestrial ecosystem [6]. Thus, the effluent released by the solar saltworks can cause the pollution of the ecosystem estuaries/marine, with change in water quality and consequent migration and/or death of fish, mollusks and crustaceans [6,7]. This effluent can modify the abiotic characteristics of the system. Significant temperature increases in bodies of water, for example, are generally due to discharges of origin industrial, can cause negative impacts on water bodies. These variations sudden surges in water have significant effects on aquatic ecosystems that aquatic organisms are affected by temperatures outside their limits of thermal tolerance, which negatively influences their growth and reproduction [8,9].

From this perspective, environmental monitoring consists of measuring a few indicators and parameters, in order to verify whether certain impacts are taking place, and its magnitude can be dimensioned and the efficiency of any preventive measures adopted. The elaboration of a record of the results of the monitoring is of fundamental importance for monitoring the situation, both for the company and for the Government, as well as for the realization of audit [9].

In view of the above, there is a clear need for studies to assess the real environmental impacts of a solar saltwork activity on coastal ecosystems. Thus, the objective was to evaluate the estuaries environmental monitoring associated with solar salt production in the Brazilian semiarid.

MATERIAL AND METHODS

The study was developed in the area of influence of a large saline, located in the Conchas’ river estuary, municipality of Porto do Mangue, inserted in the region of Salt Coast, north coast of Brazil (Figure 1). To identify the environmental impacts, the effects of the saline operation were analyzed, represented by the discharge of effluents resulting from the salt production process on the water quality of the estuary.

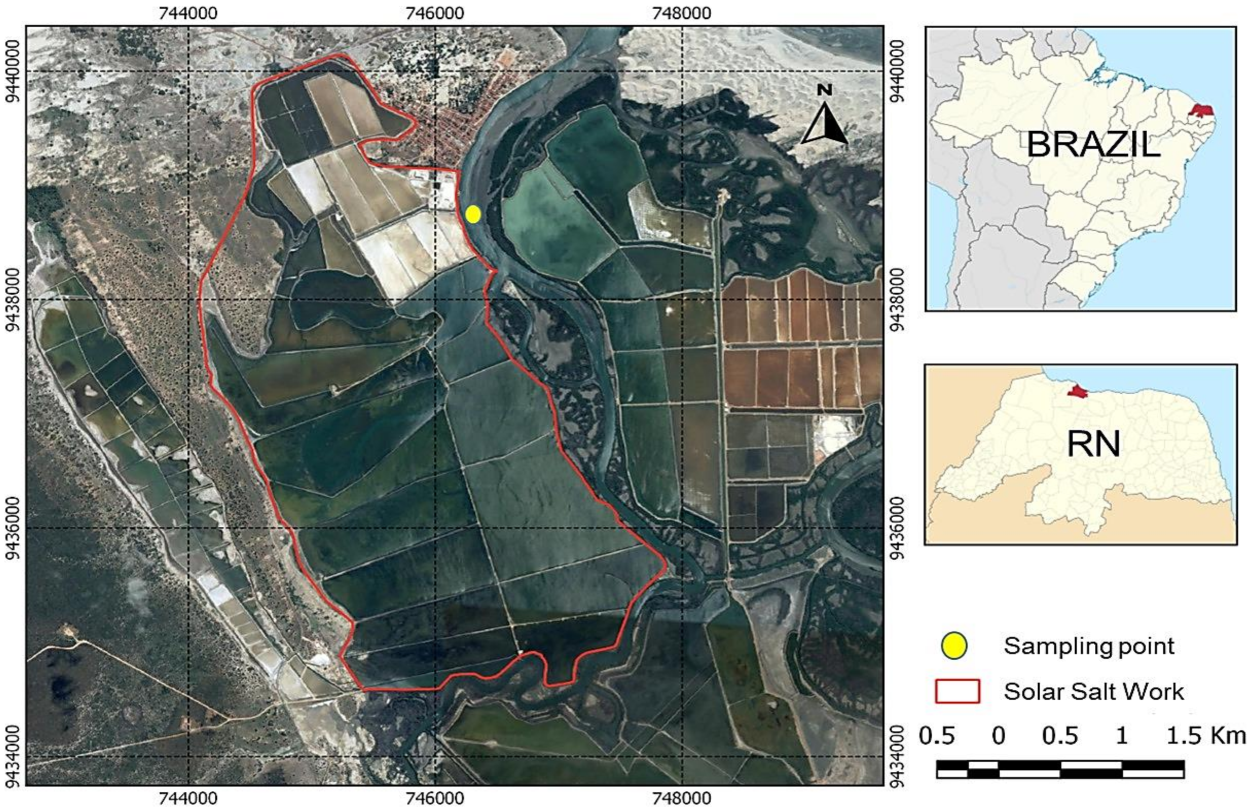

Figure 1. Study area map, located in the Conchas’ river estuary, municipality of Porto do Mangue/RN, hydrographic basin of the Piranhas/Açú’s river.

For three years – from January 2015 to December 2017 –, monitoring of water quality in the estuary for non-productive – or rainy -, periods, January to June, and productive – drought –, July to December saltwork. A collection site was established immediately in front of the solar saltwork discharge channel (5°4'28.04"S; 36°46'41.27"O), and samples were collected monthly, at 30 cm depth, always during tides high, totaling 36 samples.

The following parameters were monitored: salinity, pH, calcium, magnesium, dissolved oxygen, chlorophyll *a* and rainfall, according to the methodology described by Fernandes and coauthors [9]. Salinity was measured in the field with the aid of a portable refractometer. The pH was determined by the potentiometer method, using a bench pH meter, equipped with a glass electrode. Calcium and magnesium concentrations were analyzed by titration with EDTA (Ethylenediamine tetraacetic acid) and the Eriochrome Black indicator. Dissolved oxygen was determined in the field by the polarographic method, with an electrode immersed in a standard electrolyte solution and a semipermeable membrane, with automatic compensation of temperature and salinity.

To determine the chlorophyll *a* concentration, the samples were concentrated under negative pressure, in glass fiber filters of 47 mm in diameter, being dissolved with 90% acetone. After 24 hours of extraction, in the dark and at low temperature, absorbance measurements were made spectrophotometry at 665 nm and 759 nm wavelength, before and after acidification with 1 N HCL. Chlorophyll *a* concentrations were determined mathematically.

During the production period, collections were carried out concurrently with the discharge of effluents, one hour after the beginning of the disposal. Additionally, the values referring to the pluviometric precipitation registered in the solar saltwork were collected, as well as the monthly number of effluent discharges carried out during the entire evaluated period.

The data were initially submitted to the Cramer-von Mises test (normality) and Levene's test (heteroscedasticity) and, since then, the values referring to the limnological variables were subjected to analysis of variance and F test at 5% probability. The data were evaluated using the statistical software R [10].

RESULTS

The average salinity recorded in the study area was 37.11, and remained above 30.00 during practically the entire period evaluated. The salinity value varied according to seasonality, registering lower values during the first semesters of each year, rainy season in the region, and higher values during the second semester of each year, dry season (Figure 2).

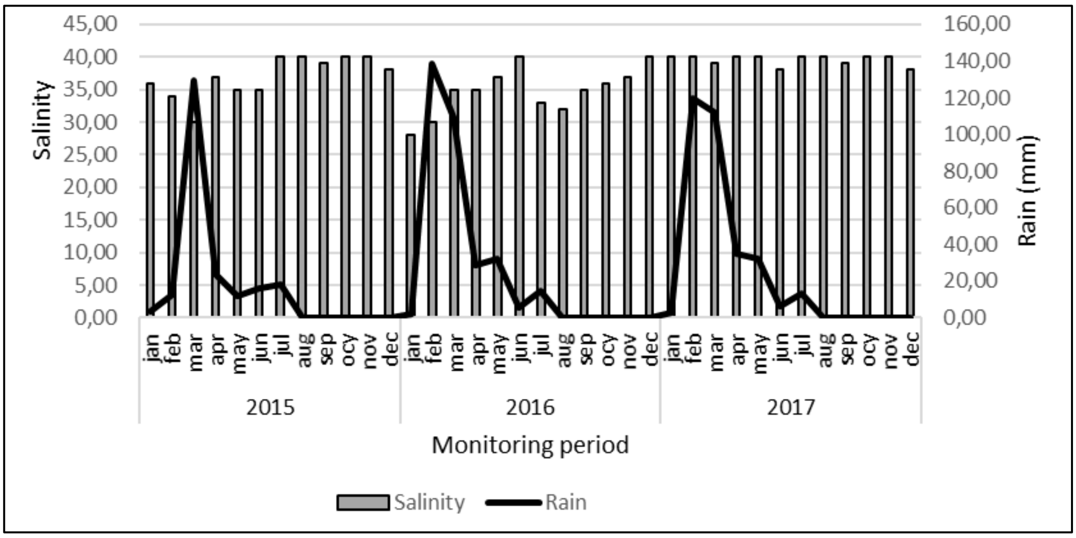

Figure 2. Relationship between salinity, represented by vertical bars, and rainfall in the study area, represented by the bold line, between January 2015 and December 2017.

The calcium and magnesium ions showed an average concentration of 440.00 mg/L and 1280.00 mg/L respectively, values that were according to the limits historically observed for a saline estuary in the analyzed region. In general, calcium and magnesium concentrations followed variations in salinity, indicating that there were no disturbances in the ionic proportion during the monitored period (Figure 3).

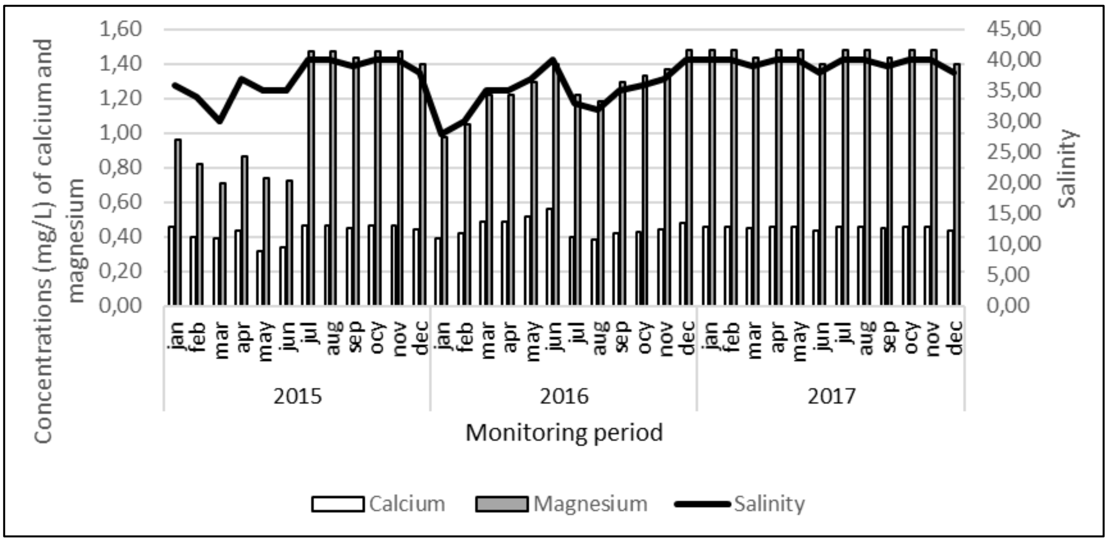

Figure 3. Relationship between salinity and concentrations (mg/L) of calcium and magnesium in the study area, between January 2015 and December 2017.

The pH showed an average of 7.93 and was not influenced by the solar saltwork operation, varying slightly during the monitored period, and remained permanently alkaline and within the limits established by CONAMA [11] for saline waters – Class 1 – , which is between 6.50 and 8.50 (Figure 4).

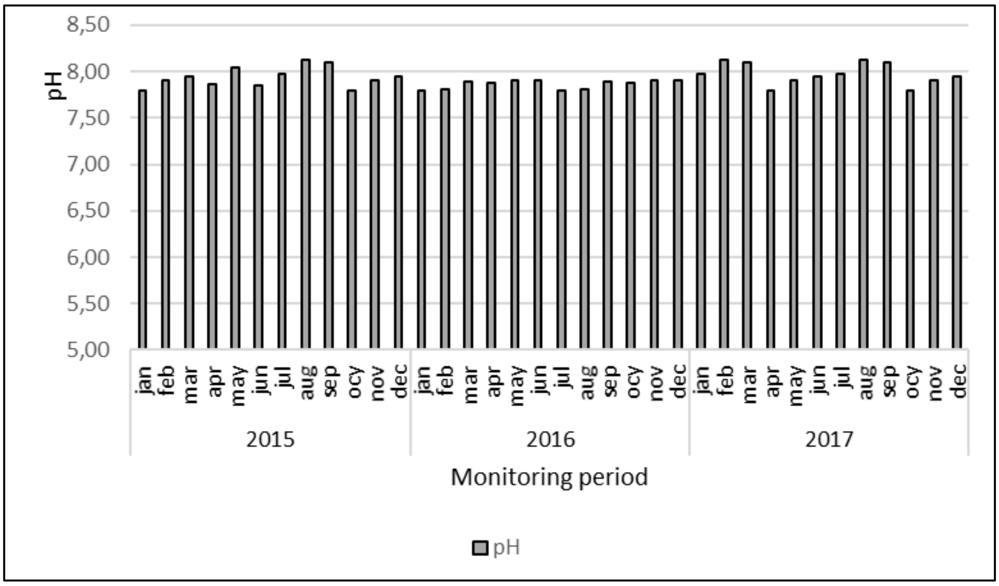

Figure 4. Monthly average pH (UpH) in the study area, between January 2015 and December 2017.

Dissolved oxygen registered an average of 6.92 mg/L and varied from a minimum concentration of 6.40 mg/l to a maximum of 7.60 mg/L (Figure 5), with no influence of the solar saltwork operation.

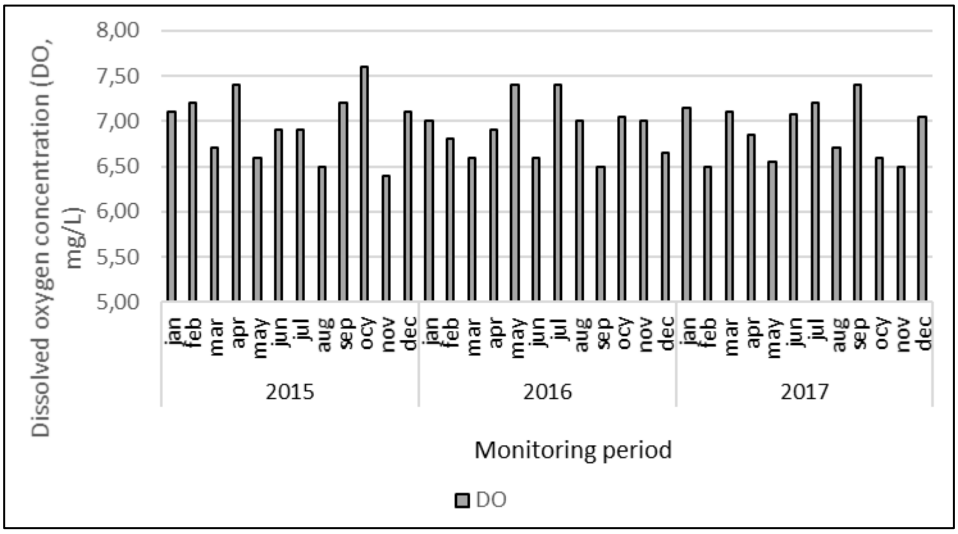

Figure 5. Dissolved oxygen concentration (mg/L) in the study area, between January 2015 and December 2017.

The chlorophyll a concentration varied between a minimum of 1.05 µg/L and a maximum of 4.10 µg/L (Figure 6).

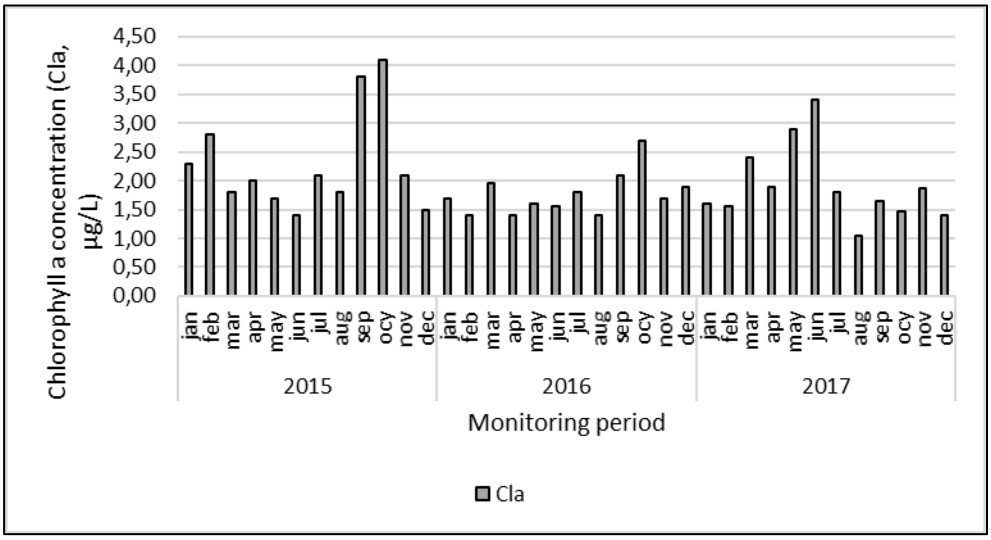

Figure 6. Chlorophyll *a* concentration (µg/L) in the study area, between January 2015 to December 2017.

Among the monitored limnological variables, only salinity and magnesium concentration showed significant differences between the operational and non-operational periods of the solar saltwork (Table 1).

Table 1. Relationship between monitored limnological variables and the period (productive and non-productive) of saline.

Parameters	Period		Statistic			
	Non-productive	**Productive**	**P**	**SD**	**SE**	**CV (%)**
Salinity *	36.06	38.16	0.0003	3.29	2.62	15.24
Calcium (mg/L)	441.67	446.11	0.3589	44.30	44.72	27.05
Magnesium (mg/L)*	1154.00	1402.00	0.0001	250.02	179.70	14.05
pH (UpH)	7.91	7.93	0.0469	0.10	0.09	1.20
Dissolved oxygen (mg/L)	6.91	6.93	0.33	0.31	4.79	6.91
Chlorophyll *a* (µg/L)	1.96	2.01	0.67	0.67	24.02	1.96

* Line averages differ by the F test (P<0.05); P- Probability; SD – Standard Deviation; SE - Standard Error of the Mean; CV- Coefficient of variation.

DISCUSSION

The average salinity, which characterized the saline environment according to CONAMA [11]. This parameter varied according to seasonality, registering lower values during the first semesters of each year, rainy season in the region, and higher values during the second semester of each year, dry season.

Salinity indicates the total ions dissolved in the water, being a measure of concentration determined mainly by the relationship between rainfall and evaporation [12]. Thus, lower salinity values were expected to be recorded during the first half of each year. During the dry season, the estuaries areas of most rivers in the Brazilian semiarid, which are intermittent and flow only during the rainy season, suffer strong penetration from marine waters, which are exposed to the evaporation process [13], and as a consequence, many estuaries located in the semiarid are classified as saline or hypersaline [12,14]. In addition, in the dry season, estuaries plains are flooded only in spring tides, promoting a gradual increase in salinity [15]. Fernandes and coauthors [16], when evaluating the Apodi-Mossoró river estuary, they recorded an average salinity of 34.90%, being the regime predominantly euhaline. That variation of salinity in different estuaries, as well as the instability of its environmental facts are inherent aspects of estuaries [18].

As for the pH, in estuaries regions, it is known that it is related to the amount of decomposing organic matter, which is a limiting factor, both for the mixture of carbon dioxide and for dissolved oxygen. According to the literature, state that the pH varies according to the ebb and flow of the tides, as well as in relation to the temperature [18]. In this context, when researchers evaluating the pH of the Apodi-Mossoró river estuary, also on the Salt Coast of Rio Grande do Norte, Brazil, recorded pH also alkaline and little variable (average of 7.7) and correlated this fact to the great influence exerted by water of the sea [19].

Dissolved oxygen is influenced by factors such as gas exchange between water and atmosphere, photosynthesis, decomposition of organic matter, temperature, salinity, and is fundamental for the metabolism of ecosystems and indispensable for fauna [19,20]. Throughout the evaluated period, oxygen remained above the minimum limit established by CONAMA [11] for saline waters, Class 1, which is 6.00 mg/l, which characterized the system as well oxygenated. This could be due to the high intensity of air currents, which can increase the oxygen input into the water by diffusion.

The chlorophyll a concentration characterized the monitored area as oligotrophic during the whole period evaluated [21], not differing between the productive and non-productive periods. Corroborating this result, it was recorded by the literature an average concentration of 3.49 µg/L of chlorophyll a in the Apodi/Mossoró estuary [19], and also characterized this ecosystem as oligotrophic. According to these authors, chlorophyll a is an important parameter for establishing the trophy of an ecosystem, in addition to being evidence of phytoplankton growth.

Fernandes and coauthors [9], in turn, when evaluating the Conchas' river estuary, based on average concentration values chlorophyll a it was found that the system behaved part of the year as oligotrophic (first and fourth trimester) and part as mesotrophic (second and third), corroborating the hypothesis of the combined effect of the induced nutrient input by rainfall and the reduction of water turbidity.

It is important to note that during the monitored period, microalgae blooms were not observed. The proliferation of these microorganisms is associated with the process of artificial eutrophication, resulting from the large supply of organic matter, high intensity of light and heat and alkaline waters [22]. Therefore, the average concentrations of chlorophyll a, associated with the absence of the microalgae blooming phenomenon in the evaluated estuary, ensure the studied area is not undergoing a water eutrophication process.

However, it should be noted that even with an increase in the average salinity and magnesium in the productive period, the classification of the evaluated estuary was not changed, remaining the same as saline, and the salinity values remained within the limits considered appropriate for organism's estuaries and marine (less than 40.00). This difference can be explained for the most part by seasonality, since the productive and non-productive periods coincide with the dry and rainy seasons respectively.

Based on the results of environmental monitoring in the period covered by this study, it is concluded that the results issued are properly related with the standards required by current legislation, demonstrating that there is no degradation of the water quality of the estuary of the Conchas' river resulting from the functioning of the saline in question. However, it should be noted that the results portray periods of high tide, when marine input may overlap any other influence, and, it is worth noting that this is an anthropic activity, and which monitoring programs are essential to evaluate systematically the environmental quality parameters and identify possible negative impacts arising from salt production, based on water evaporation navy [9].

CONCLUSION

The functioning of the analyzed solar saltwork did not cause significant changes in the water quality parameters of the estuary, with the differences in salinity and magnesium concentration being those resulting from the region's seasonality. However, it should be noted that the results portray periods of high tide, when marine input may overlap any other influence. The use of control measures in the discharge of effluents allows the development of saltwork activity sustainably, since salt production has great relevance in the local and national socioeconomic aspects.

Conflicts of Interest: The authors declare no conflict of interest.

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ERRATUM

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