DOI:10.21715/GB2358-2812.2016302202

Physicochemical parameters in estuarine zones of the Todos os Santos Bay in Bahia, Brazil

Alexandre Dacorso Daltro Milazzo[1]
Manoel Jerônimo Moreira Cruz[1]
Eduardo Gomes Vieira de Melo[2]

[1] Geoscience Institute
Department of Geology
Federal University of Bahia
Barão de Jeremoabo – Ondina
Salvador, Bahia, Brazil.
40170-115

[2] Geoscience Institute
Department of Geochemistry
Federal University of Bahia
Barão de Jeremoabo – Ondina
Salvador, Bahia, Brazil. e-mail:
40170-115

alexandremilazzo@yahoo.com.br
jeronimo@ufba.br
eduvieira81@yahoo.com.br

*corresponding author

Resumo

Os parâmetros físico-químicos em águas superficiais e sedimentos são importantes para entender a dinâmica estuarina. Diferentes contribuições de processos naturais ao longo do ano, como chuva, vento, radiação solar e entrada de água, bem como geomorfologia afetarão os parâmetros fisicoquímicos. O presente estudo foi realizado para determinar como a diferença espaço-temporal desempenha um papel nos parâmetros físico-químicos em três locais diferentes da Baía de Todos os Santos. Isso envolveu a análise de pH, Eh (mV), temperatura (ºC), salinidade (‰), oxigênio dissolvido (mg L^{-1}) e condutividade (ms cm^{-1}) na água e pH, Eh (mV), Temp. (ºC) e condutividade (ms cm^{-1}) nos sedimentos. O tamanho das partículas e a matéria orgânica também foram analisados nos sedimentos. Os resultados mostraram que os valores de todos os parâmetros foram diferentes de acordo com o tempo de amostragem, bem como a localização na baía. A temperatura e a salinidade das águas superficiais, por exemplo, foram maiores durante a estação seca (1º e 3º campanha de amostragem). O pH das águas superficiais foi maior no rio Maragogipe (7,70) e para o sedimento, o rio São Paulo apresentou o maior pH (7,23). A matéria orgânica no sedimento apresentou menor porcentagem durante a estação chuvosa (2ª campanha de amostragem) e este parâmetro está fortemente associado ao tamanho das partículas. Esses resultados sugerem que a variação espacial ao longo da baía juntamente com a sazonalidade afetam todos os parâmetros fisicoquímicos no estuário.
Palavras-chave: parâmetros fisicoquímicos, variação espaço-temporal, sazonalidade

Abstract

The physicochemical parameters in both surface waters and sediments are important to understand estuarine dynamics. Different input of natural processes along the year such as rainfall, wind, solar radiation and water input as well as geomorphology will affect the physicochemical parameters. The present study was carried out in order to determine how the spatial-temporal difference plays a role in the physicochemical parameters at three different locations from the Todos os Santos Bay. This involved analyzing pH, Eh (mV), temperature (ºC), salinity (‰), dissolved oxygen (mg L^{-1}) and conductivity (ms cm^{-1}) in the water and pH, Eh (mV), Temp. (ºC) and conductivity (ms cm^{-1}) in the sediments. Particle size and organic matter were also analyzed in the sediments. The results showed that the values of all parameters were different according to the sampling time as well as the location in the bay. The temperature and salinity of the surface water, for example, were higher during the dry season (1^{st} and 3^{rd} sampling campaign). The pH of the surface water was higher in the Maragogipe River (7.70) and for the sediment São Paulo River showed the highest pH (7.23). The organic matter in the sediment showed the lower percentage during the rainy season (2^{nd} sampling time) and this parameter is strongly associated with the particle size. These results suggest that spatial variation along the bay together with the seasonality affect all the physicochemical parameters in the estuary.
Keywords: physicochemical parameters, spatial-temporal variation, seasonality

1. Introduction

One of the most common and the most important resource on earth, which facilitates life on this planet, as we know, is water (Anitha & Surgitha 2013). The marine environment is an essential part of the global life, mainly in the coastal and estuary areas (Dixit *et al*. 2013). As a transitional area between land and sea, estuarine zones are important for fishers in tropical regions, as economic activity or like places for feeding (Gadhia *et al*. 2012).

With its mangrove forests, which brings a significant ecological importance, estuarine areas are a complex and very dynamic kind of aquatic environment, mainly because of the mix between both sea and river waters, where many physicochemical processes take place and will affect the quality of water (Anitha & Surgitha 2013). The terrestrial and oceanic inputs in estuarine zones are modified by biogeochemical processes, which are modulated by many mechanisms, such as wind, water temperature, waves, tides or freshwater discharge (Regnier *et al*. 2013).

The Todos os Santos Bay, in Salvador, located in the Recôncavo Baiano region, North East of Brazil, is a unique area that has many ecosystems with a large fauna and flora biodiversity. The Bay is also used for industrial activities, which on one hand brings economic value for society, but on the other hand has led to possible exposure damage and deterioration of the environment. Lots of biological processes in aquatic ecosystems are influenced by many different factors, such as pH, redox conditions, organic matter, mineral particles and salinity (Du Laing *et al*. 2008; Reitermajer *et al*. 2011). These factors may vary during the year, mainly because of the difference in rainfall intensity between seasons, consequently, bringing important impacts on the environment (Nizoli & Luiz-Silva 2009). The Todos os Santos Bay is unique because it consists of a range of different habitats with different characteristics. This spatial variation in characteristics, together with the temporal variation, may however, lead to different values and results for many parameters (Queiroz & Celino 2008). The knowledge about how the physicochemical parameters are affected by the seasonality and river shapes can be a key to assess the quality of the mangrove areas in the bay.

The aim of this study is to identify how the variation in time and location affect the physicochemical characteristics of three different mangrove areas in the Todos os Santos Bay. This involved analyzing pH, Eh (mV), temperature (ºC), salinity (‰), dissolved oxygen (mg L^{-1}) and conductivity (ms cm^{-1}) in the water and pH, Eh (mV), Temperature (ºC) and conductivity (ms cm^{-1}) in the sediments. Particle size and organic matter were also analyzed in the sediments.

2. Materials and methods

This study was carried out in the Todos os Santos Bay (32º 02' 30" - 38º 37' 30"W and 13º 07' 30" - 12º 37' 30"S) in Brazil, in three different estuarine zones near the (A) Maragogipe, (B) Jaguaripe and (C) São Paulo Rivers. The Todos os Santos Bay is the biggest and most important navigable bay of the Brazilian coast, with a surface area of about 1.200 km² and a coast length of 462 km.

These estuarine zones, near the Maragogipe, Jaguaripe and São Paulo Rivers, where a magnificent mangrove system develops, have a fundamental importance to the local food chain and also to the livelihood of many of the inhabitants of the region. Even though they belong to the same Bay, the three areas have different characteristics due to the spatial variation. These estuarine ecosystems have been affected by many human activities, such as contamination by chemical industries, which have contributed to their deterioration (De Carvalho 2007).

Geologically, the Todos os Santos Bay is included in the sedimentary basin of the Recôncavo Baiano. The climate is tropical-humid and presents a remarkable seasonal cycle (Figure 2). Rainfall in this region is around 300 mm $month^{-1}$ between April and June, characterizing the wettest period. Between January and March, the rain is less intense and well distributed with a precipitation of around 125 mm $month^{-1}$ and an average annual temperature of about 25 ^{o}C (Kirimurê 2013).

The economic activities in this region are considered as industrial, and cases of oil spills have been reported, as well as emissions of industrial and domestic effluents from municipalities around the region (De Jesus 2011; Milazzo *et al*. 2014).

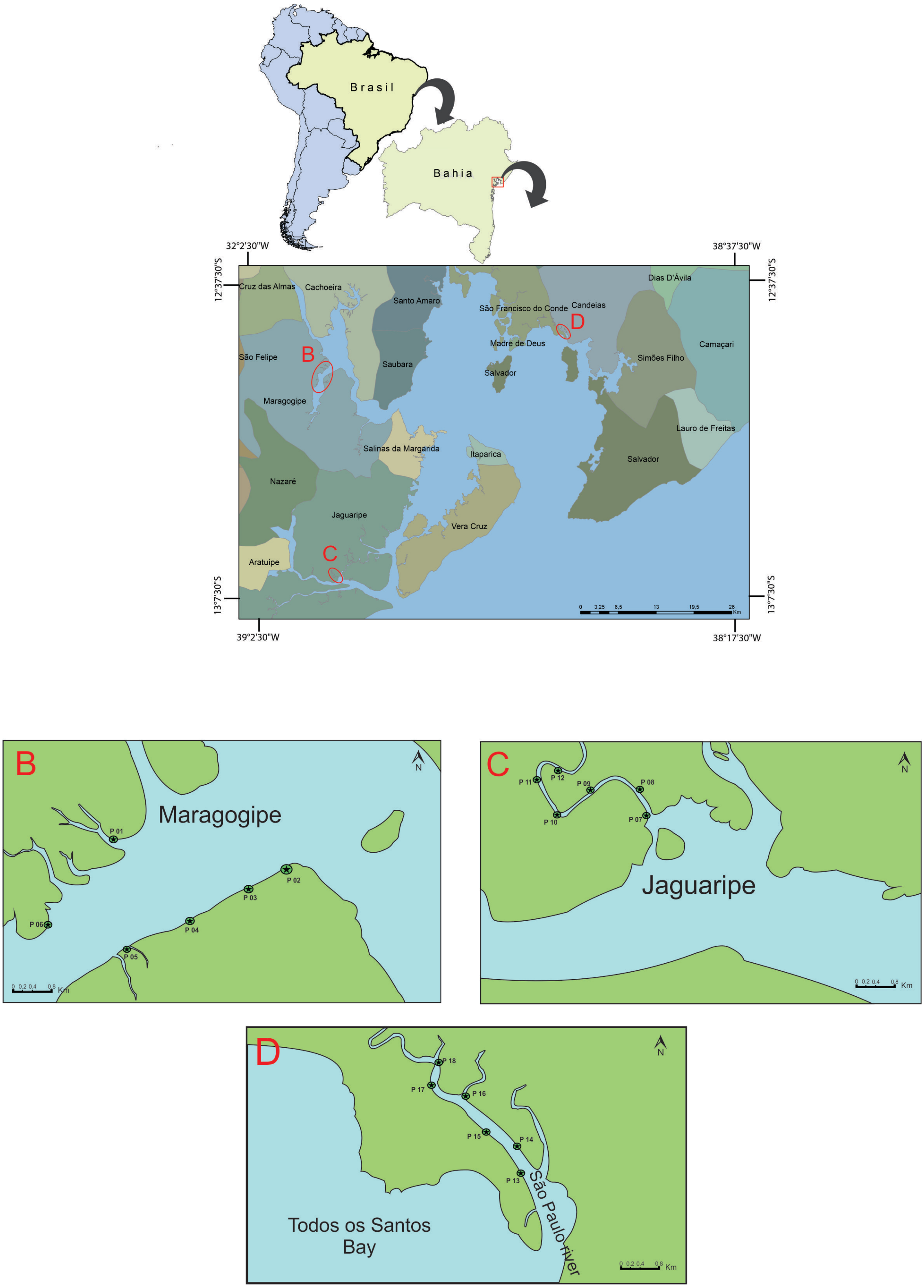

Figure 1

Location of the sampling sites used for this study. Insert shows a map of the Bahia region in Brazil with the Todos os Santos Bay. The detailed overview of the Todos os Santos Bay area shows the sampling sites near the Maragogipe (A), Jaguaripe (B) and São Paulo (C) Rivers.

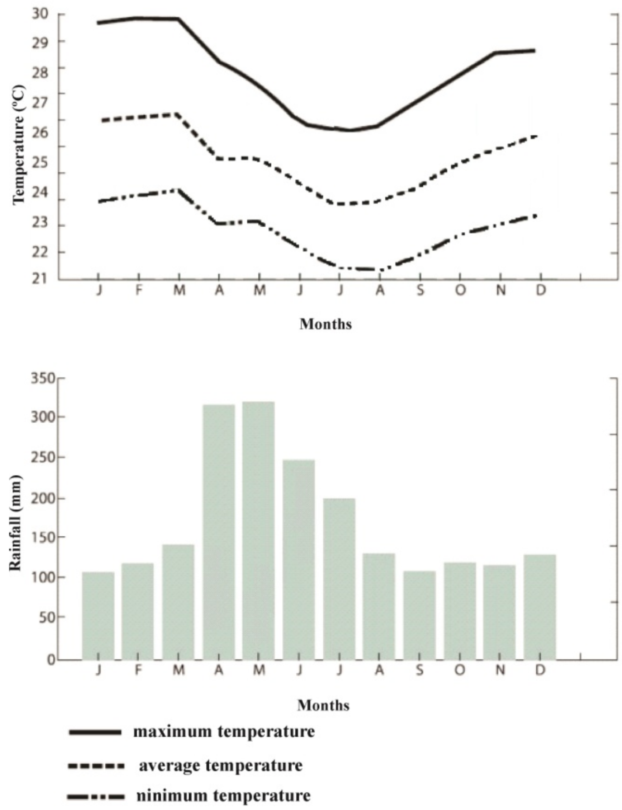

Figure 2
Average seasonal variation of temperature and rainfall in the study area registered by the Ondina Weather Station for the period of 1961-2009 (INMET 2015). This station, located in Salvador-Bahia, is the closest weather station of the Todos os Santos Bay.

2.1 Sampling

The field work was carried out in three periods, March 2014, January 2015 (dry season) and August 2014 (rainy season). Sampling was always carried out during the low tide (Table 1).

Sediment and surface water samples were collected from 18 points (6 in each estuary), with a spatial distance of approximately 200 m between each sampling point. This distance is sufficient to consider sampling points as true replicates. The sampling points were randomly chosen across each sampling location, in order to avoid any bias in the results.

Table 1 Location, dates, time and tide height (m) of the samplings of the three locations in the Todos os Santos Bay, Bahia, Brazil, using the Madre de Deus Port tide as reference.

	Season								
	Date			Hour			Tide height (m)		
Location	1st (2014)	2nd (2014)	3rd (2015)	1st (2014)	2nd (2014)	3rd (2015)	1st (2014)	2nd (2014)	3rd (2015)
Maragogipe River	18/03	26/08	07/01	10:51 a.m.	10:02 a.m.	11:09 a.m.	0.2	0.2	0.4
Jaguaripe River	20/03	27/08	08/01	10:51 a.m.	10:54 a.m.	11:47 a.m.	0.3	0.3	0.5
São Paulo River	21/03	29/08	09/01	12:19 a.m.	11:49 a.m.	12:13 p.m.	0.4	0.4	0.6

2.2 Water collection and preparation for analysis

Surface water samples (500 mL) were taken at a depth of 0 - 20 cm using polyethylene bottles and the physicochemical parameters (pH, Eh (mV), temperature (ºC), salinity (‰), conductivity (ms cm^{-1}) and dissolved oxygen (mg L^{-1}) were monitored at each sampling point. For all measurements, a HORIBA U-50 multiparameter water quality was used.

2.3 Sediment collection and preparation for analysis

For the sediments, approximately 300 g were sampled from the top 0 - 15 cm layer, and stored in polyethylene packages with a sufficient amount of water from the sampling site to preserve their characteristics. The samples were placed in coolers with ice to maintain a temperature of 4 ^{o}C, according to the methodology described by Jesus *et al* (2003). The cores were taken to the laboratory, where particle size distribution (classified as sand, silt and clay), and organic matter content were analyzed. To measure the physicochemical parameters (pH, Eh (mV), temperature (ºC) and conductivity (ms cm^{-1})), a HORIBA U-50 multiparameter water quality was used.

2.4. Data analysis

The data were analyzed using STATISTICA 7 to observe summary statistics and trends and behaviors of the physicochemical parameters. Microsoft Office Excel 2007 as well as the STATISTICA 7 were used to correlate the physicochemical parameters.

3. Results

The physicochemical parameters measured in surface waters and sediments from the Maragogipe, Jaguaripe and São Paulo Rivers, sampled in three different seasons, are summarized in Table 2. In the surface waters, the pH increased with time for all rivers, except for the São Paulo River which had the highest pH (7.29) during the second season. The pH of the sediments showed the same increasing trend with time, however, during the last sampling season, sediment pH in the Maragogipe River was lower than in the second season.

The Eh values showed a quite similar behavior for both surface waters and sediments. In the Maragogipe River, the Eh values were negative in all seasons. In the São Paulo River, Eh of surface water was negative at the first and second sampling. For the sediments, the values in general were negative during the first and last season and positive in the second season.

During the second sampling (rainy season), temperatures were lower than at the first and third sampling (dry season). In the sediments, the same trend was noticed for Jaguaripe and São Paulo Rivers while in the Maragogipe River temperature increased from the first to the third sampling.

Dissolved oxygen concentrations showed the same trends in the Maragogipe and São Paulo Rivers with the highest values recorded during the first (6.9 and 3.6 mg L^{-1}) and third (7.7 and 3.6 mg L^{-1}) seasons. In the Jaguaripe River the highest mean of the dissolved oxygen concentration was measured during the third season (9.3 mg L^{-1}), while the first and second seasons showed similar results (3.8 mg L^{-1}).

The conductivity of the surface water showed a different trend for the different Rivers. In the Maragogipe River, conductivity was highest during the second season (44.7 ms cm^{-1}), while in the São Paulo River it was lowest (49.9 ms cm^{-1}) during the second season. In the Jaguaripe River, the conductivity increased from the first to the third sampling. The conductivity of the sediments of the Jaguaripe and São Paulo Rivers was also lowest during the rainy season, while it was highest for the Maragogipe River sediments (49.5 ms cm^{-1}) during the rainy season.

Salinity of the São Paulo River was highest (34.6 and 33.1 ‰) during the first and third season, respectively, while in the Maragogipe River the highest value (28.6 ‰) was recorded during the second season. In the Jaguaripe River, salinity increased from the first to the third season, from 14.3 ‰ to 23 ‰.

Table 3 shows the particle size distribution (sand, silt, clay) and organic matter content of the sediment for each river in the three different sampling seasons. Organic matter content showed the same trend for all three rivers, being much lower in the rainy season (2nd sampling) than in the dry seasons. Overall, the São Paulo River sediment had the lowest organic matter content.

Table 2 Physicochemical parameters of surface waters and sediments in the Maragogipe, Jaguaripe and São Paulo rivers, Brazil, sampled in three different seasons (1st: March 2014; 2nd: August 2014; 3rd: January 2015). The values shown are mean ± standard deviation (n = 6).

Variable		Season (Mean ± St.dev.)		
	River	1st	2nd	3rd
pH (water)	Maragogipe	6.75 ± 0.29	7.59 ± 0.13	7.70 ± 0.43
	Jaguaripe	5.44 ± 0.26	6.81 ± 0.19	7.25 ± 0.09
	São Paulo	5.91 ± 0.25	7.29 ± 0.16	7.05 ± 0.42
Eh (mV) (Water)	Maragogipe	-7.8 ± 17.9	-30.1 ± 8.0	-25.1 ± 27.3
	Jaguaripe	3.8 ± 16.7	16.0 ± 11.8	2.6 ± 5.9
	São Paulo	-22.8 ± 14.9	-12.3 ± 9.9	16.0 ± 25.4
Temp. (ºC) (Water)	Maragogipe	29.2 ± 0.5	26.1 ± 1.1	30.7 ± 1.3
	Jaguaripe	28.4 ± 0.9	24.4 ± 0.3	27.6 ± 0.2
	São Paulo	29.7 ± 0.6	25.5 ± 0.6	27.3 ± 0.4
Salinity (‰) (water)	Maragogipe	22.3 ± 4.1	28.6 ± 2.1	22.0 ± 1.4
	Jaguaripe	14.3 ± 2.8	16.0 ± 3.5	23.0 ± 2.0
	São Paulo	34.6 ± 3.8	32.1 ± 0.9	33.1 ± 3.6
D.O. (mg L^{-1}) (water)	Maragogipe	6.9 ± 1.0	5.9 ± 1.2	7.7 ± 0.9
	Jaguaripe	3.8 ± 0.4	3.8 ± 0.3	9.3 ± 1.1
	São Paulo	3.6 ± 0.3	3.1 ± 0.4	3.6 ± 1.4
Cond. (ms cm^{-1}) (water)	Maragogipe	35.8 ± 6.0	44.7 ± 2.3	35.4 ± 1.9
	Jaguaripe	24.0 ± 4.2	26.5 ± 5.3	36.5 ± 2.7
	São Paulo	52.7 ± 4.6	49.9 ± 1.4	50.6 ± 4.7
pH (sed)	Maragogipe	6.81 ± 0.13	7.10 ± 0.36	6.80 ± 0.18
	Jaguaripe	6.71 ± 0.37	6.99 ± 0.20	7.21 ± 0.14
	São Paulo	6.85 ± 0.21	7.06 ± 0.23	7.23 ± 0.18
Eh (mV) (sed)	Maragogipe	-5.6 ± 7.1	-5.6 ± 21.2	13.6 ± 10.5
	Jaguaripe	-4.6 ± 10.9	4.1 ± 12.5	-1.5 ± 7.4
	São Paulo	-5.0 ± 14.0	0.0 ± 13.3	-3.1 ± 10.7
Temp. (ºC) (sed)	Maragogipe	27.5 ± 1.3	28.4 ± 2.6	30.7 ± 2.0
	Jaguaripe	27.6 ± 1.3	25.5 ± 0.7	29.5 ± 2.4
	São Paulo	28.6 ± 0.6	26.9 ± 1.5	28.9 ± 1.1
Cond. (ms cm^{-1}) (sed)	Maragogipe	42.4 ± 3.7	49.5 ± 3.8	44.6 ± 3.6
	Jaguaripe	40.1 ± 3.4	31.3 ± 3.7	41.1 ± 3.9
	São Paulo	55.3 ± 2.0	51.4 ± 2.2	56.5 ± 1.8

Table 3 Particle size distribution (silt, clay and sand) and organic matter contents (O.M.) (in %) of sediments in the Maragogipe, Jaguaripe and São Paulo Rivers, sampled in three different seasons: March 2014 (1st), August 2014 (2nd) and January 2015 (3rd).

Variable		Season		
	River	1st	2nd	3rd
Silt	Maragogipe	24.8	35.5	36.2
	Jaguaripe	28.2	29.0	34.0
	São Paulo	29.9	27.2	28.3
Clay	Maragogipe	26.6	41.1	47.3
	Jaguaripe	23.0	18.4	24.5
	São Paulo	17.1	29.4	30.5
Sand	Maragogipe	48.4	23.2	16.3
	Jaguaripe	48.7	52.5	41.4
	São Paulo	52.8	43.3	41.0
O.M.	Maragogipe	10.3	6.1	13.2
	Jaguaripe	10.2	8.2	12.5
	São Paulo	9.7	5.6	9.6

Particle size distribution also showed some variation between seasons and rivers. Clay content, for instance, showed the same trend in the Maragogipe and São Paulo Rivers, increasing with time from 26.6 to 47.3% in the Maragogipe River and from 17.1 to 30.5% in the São Paulo River. In the Jaguaripe River, sediment clay content was highest (23.0 and 24.5%) during the first and third season and lowest (18.4%) during the second season.

4. Discussion

For both water and sediment samples, the physicochemical parameters analyzed at the three sampling locations showed different spatial and temporal trends during the sampling period of this study, similar results were found by Milazzo et al. (2014). Due to its characteristic and directly contact to the environment, the temperature of water and sediment is the first to react to the air temperature and water input. Once the rainy season starts, the temperature normally decreases, but all other parameters analyzed had also different behaviors during the different seasons. In some cases as the pH and salinity in the Maragogipe River, and the D.O. levels for all rivers studied, the results were not as expected, therefore, indicating that a combination of many factors can affect the physicochemical parameters of water and sediment according to the place of study.

In the present study, as expected, temperature of the surface water at all locations decreased during the rainy season. During June, July and August, the land breezes, the higher precipitation and fresh water influx together were essential for the lower temperatures compared with the dry season. The higher intensity of solar radiation and evaporation also affected surface water temperature, and as a consequence, during the dry season (1^{st} and 3^{rd} field works) this parameter was higher. This result was the same found by Dixit *et al*. (2013) and Anitha & Surgitha (2013).

The temperature of the sediments followed the same trends of the surface waters being higher during the dry season, except in the Maragogipe River which the temperature increased from the 1^{st} to the 3^{rd} sampling (Table 2). This situation might be connected with the same reasons (high intensity of solar radiation and evaporation) which affected the temperature of the surface waters.

The pH values from both surface waters and sediments varied between seasons and rivers, going from 5.44 to 7.70 in the surface waters and from 6.71 to 7.23 in the sediments (average values), ranging from acid to alkaline. In the surface waters the highest pH values were recorded in the Maragogipe River, which might be attributed to that region receiving more effluent discharge (mainly domestic ones) which may make the water more alkaline (Dublin-Green 1990), as reported by Otero el al. (2008), this region suffer with cases of household sewage and industrial waste as well. Regarding the Jaguaripe and São Paulo Rivers, the latter one had the highest pH during the 1^{st} and 2^{nd} sampling (Table 3). This probably is explained from sea water penetration which may lead to an increase of the pH of estuarine waters (Anitha & Sugirtha 2013). With values ranging between 7.40 and 8.50 for sea waters, pH showed the influence of the ocean, which was different depending on the location and sampling time. The São Paulo River being closer to the ocean than the other two sampling areas may be one of the explanations for the highest pH values at this location.

Water pH will affect the solubility of metal ions in the environment and their binding to solid or dissolved phases like sediment or dissolved organic carbon (Niyogi & Wood 2004). This means that pH also controls the availability of metals for uptake by organisms (Dixit *et al*. 2013), in this way, bringing consequences to the environment. In the sediments, pH variation might be important to try to understand the behavior of the metals, since this parameter can explain ion binding process in soils and sediments (Niyogi & Wood 2004). For example, at pH decreasing, higher competition of protons may cause a reduced metal binding to sediments or the other way around.

The fact that the pH ranged not only between seasons but also between locations allows us to say that the different characteristics of each location will be important to explain the behavior of this parameter. Factors like dilution of seawater by freshwater influx leading to salinity reduction, organic matter decomposition and temperature are relevant for the oscillation of the pH (Gadhia *et al*. 2012). Once those factors can be completely different between places, it is expected that the pH will also be different between locations.

Eh values of the surface waters ranged from -30.1 to 16.7 mV in the different rivers and at different sampling times. Most of the time redox potential was negative, which is normal for estuarine environments and mangrove areas with their high organic matter content (Milazzo et al. 2014). In such environments, oxygen is rapidly consumed by microorganisms, giving this ecosystem a reductive feature (Queiroz & Celino 2008). The variation in Eh values might be related with the tide and sampling time among the rivers. Also in the sediments, the redox potential was mostly negative. The variation in Eh values can be associated with the location of sampling since for each location the microbial activity may be different.

The salinity of the surface waters did not show the same trend between rivers but showed different values according to each location. Salinity is a parameter associated and affected by many factors like evaporation rates, rainfall, dilution in the estuary and mainly by the flood and ebb tides (Dublin-Green 1990; Dixit *et al*. 2013) and this parameter acts as a factor of distribution for many living organisms (Gadhia et al., 2012).

In this study, the salinity was higher in the São Paulo River during all seasons (32.1-34.6 ‰) which is easily explained from its location (closer to the sea compared to the other two rivers). Comparing both Maragogipe and Jaguaripe Rivers, the second one was expected to have shown higher salinity, but an opposite situation happened (Table 2). Due to practical problems, the second sampling in the Maragogipe River was carried out at the middle tide, in this way, there was a higher influence of the sea in the estuary. In the Jaguaripe River, a rainy day before and during the 1st season probably was the main reason for the lowest values (14.3 ‰).

Dissolved oxygen (D.O.) levels showed the same behavior for all rivers studied, being lower during the rainy season (Table 2). These results were not as expected since during lower temperatures the solubility of the gases increases, resulting in waters more oxygenated. As an important water quality indicator, D.O. has influence in many biological and chemical processes in the environment and is crucial for supporting life (Gadhia *et al*. 2012). In this research, the D.O. levels followed the same trend as temperature (Table 2). An opposite behavior was reported by Anita & Surgitha (2013).

According to Brazilian legislation (CONAMA 2005), the D.O. values shouldn't be below 5.0 mg L^{-1}. The D.O. values for the São Paulo River for all seasons and the Jaguaripe River for the 1st and 2nd samplings were below the latter limit. Low levels of D.O. in these rivers may cause reduction of some organisms like fishes; as well as an increase population of anaerobic microorganisms like bacteria can happen because of the deoxygenation of the waters. In this way, bringing a reproductive failure and death of fishes, causing changes in the local environment and modifying abundance and diversity of species (Abowei 2010). This situation might be triggered by the effects of nutrient pollution since there is no suitable sewage treatment in these locations.

The conductivity of the surface water showed opposite trends comparing the Maragogipe (with the highest value during the rainy season) and the São Paulo Rivers (lowest value in the rainy season), while in the Jaguaripe River it increased from the first to the third sampling period. The conductivity is directly related to the concentration of ions in the water and it can be a good indicator of the presence of some contaminants (Nazir *et al*. 2015).

As a result of being closer to the sea, the São Paulo River showed the highest values for conductivity in both surface waters and sediments comparing with the Maragogipe and Jaguaripe Rivers and this situation was already reported in the literature (Cox *et al*. 1967). In the surface waters, as expected, the conductivity showed the same patterns as the salinity (Figure 3). In the sediments, both Jaguaripe and São Paulo Rivers showed the same patterns with lower values in the rainy season. On the other hand, in the Maragogipe River, the highest values were during the rainy season. As it's known, the conductivity has an important relationship with metal concentration in the sediment (Nazir *et al*. 2015; Van Gestel & Koolhaas 2004), therefore, the metal behavior between these studied locations might show different values.

In the sediment, the organic matter also showed a variation between seasons, being lower during the rainy season for all rivers (Table 3). With lower temperatures, it is expected that the activities of the organisms decreases, which leads to a reduction of the degradation in the environment and consecutively of the organic matter. The organic matter content has a strong influence on cation exchange capacity, buffer capacity and on the retention of heavy metals in the sediments. During the dry season and with the highest percentage of organic matter together with the characteristic of high affinity for heavy metals (Marchand *et al*. 2001), the mangrove sediments might accumulate pollutants in the dry season, which can lead to disturbances in the environment.

The particle size distribution was different between seasons as well as between all the rivers in a general overview (Table 3).

Once the water influx from the continent as well as the sea water intrusion are different along the year and locations, the sediments will be mobilized and moved by these powers, resulting in different patterns. It is expected a relationship between the particle size and the organic matter but this situation wasn't noticed in this study. Anyhow, a special attention should be given for the clay content, since it has properties which leads in favor to binding of cations (Finzgar *et al.* 2007), which will be important to explain possible correlations with the metal concentration for example.

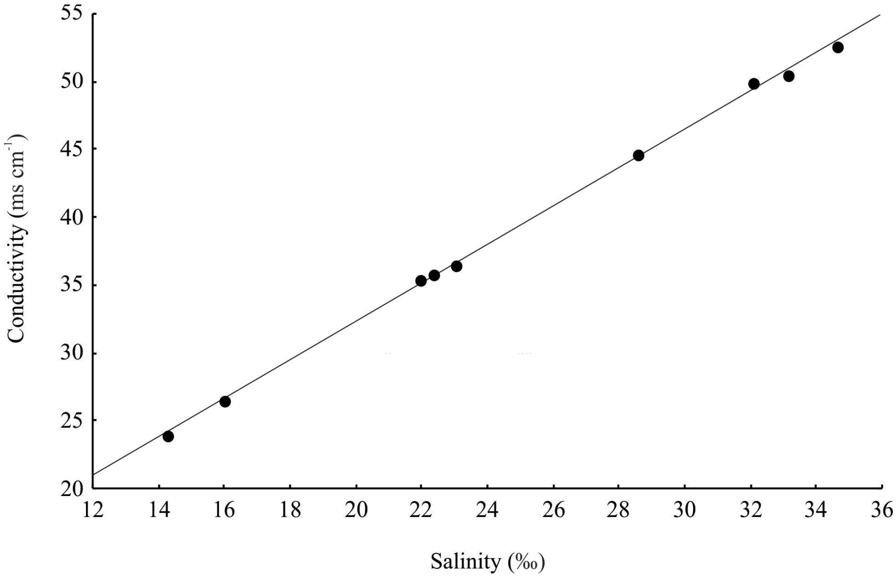

Figure 3
Relationship between average concentration of Conductivity (ms cm^{-1}) and average concentration of Salinity (‰) in the surface water of Maragogipe, Jaguaripe and São Paulo Rivers sampled in three different seasons (March 2014; August 2014; January 2015).

5. Conclusion

The estuarine waters and sediments of Maragogipe, Jaguaripe and São Paulo Rivers showed a spatial and temporal variation for all parameters. These results might be related with the different mixing process of fresh water and sea water between locations and the variation of meteorological conditions. The different characteristics between each sampling location was decisive to lead to different parameters results. All these physicochemical parameters, which are governed by many factors, might affect metal concentration in the surface waters and sediments for example and, in this way, have an influence on organisms in the environment.

Spatial and temporal studies are important in determining the possible effects of physicochemical parameters on metal concentrations in water, sediment and biota, since metals are important for the maintenance of the environment. Further investigations were done to understand the real effects of the physicochemical parameters on the metal concentration in surface waters, sediments and biota, which will bring support to future statements about estuarine zones.

6. Acknowledgements

Alexandre D. D. Milazzo received a PhD grant from the Brazilian National Council for Scientific and Technological Development (CNPq). Thanks are due to Eduardo Passos Lima for the support in the map area designing.

7. References

Abowei J.F.N. 2010. Salinity, dissolved oxygen, pH and surface water temperature conditions in Nkoro River, Niger Delta, Nigeria. *Advanced Journal of Food Science and Technology*, **2**(1):36-40.

Anitha G. & Surgitha P.K. 2013. Seasonal variations in physico-chemical parameters of Thengapattanam estuary, South west coastal zone, Tamilnadu, India. *International Journal of Environmental Sciences*, **3**(4):1253-1261. Doi:10.6088/ijes.2013030400004

CONAMA - 2005. Resolution No. 357 of the Brazilian National Environment Council, DOU NO. 53.

Cox R.A., Culkin F., Riley J.P. 1967. The electrical conductivity/chlorinity relationship in natural sea water. *Deep Sea Research and Oceanographic Abstracts*, **14**(2):203-220. Doi:10.1016/0011-7471(67)90006-X

De Carvalho L.V.M. 2007. Estudo da qualidade da água superficial em zona estuarina do rio São Paulo – Região de Candeias – BA. Master Dissertation, Geoscience Institute, Federal Universityof Bahia, 129 p.

De Jesus R.S. 2011. Metais traço em sedimentos e no molusco bivalve *Anomalocardia brasiliana* (Gmelin, 1791), municípios de madre de deus e de Saubara, Bahia. MSc. Master Dissertation, Geoscience Institute, Federal Universityof Bahia, 101 p.

Dixit P.R., Kar B., Chattopadhyay P., Panda, C.R. 2013. Seasonal variations of the physicochemical properties of water samples in Mahanadi Estuary, East Coast of India. *Journal of Environmental Protection*, **4**:843-848. Doi: http://dx.doi.org/10.4236/jep.2013.48098

Dublin-Green C.O. 1990. Seasonal variations in some physico-chemical parameters of the Bonny Estuary. Niger Delta. *Nigerian Institute for Oceanography and Marine Research Lagos*, **59**: 3-25. Doi: http://hdl.handle.net/1834/2408

Du Laing G., De Vos R., Vandecasteele B., Lesage E., Tack F.M.G., Verloo M.G., 2008. Effect of salinity on heavy metal mobility and availability in intertidal sediments of the Scheldt estuary. *Estuarine, Coastal and Shelf Science,* **77**:589-602. Doi:10.1016/j.ecss.2007.10.017

Finzgar N., Tlustos P., Lestan D. 2007. Relationship of soil properties to fractionation, bioavailability and mobility of lead and zinc in soil. *Plant soil and environment*, **53**(5):225-238.

Gadhia M., Surana R., Ansari E. 2012. Seasonal variations in physico-chemical characteristics of Tapi Estuary in Hazira Industrial area. *Our Nature*, **10**:249-257. Doi: http://dx.doi.org/10.3126/on.v10i1.7811

INMET - Instituto Nacional de Meteorologia 2015. Climatologia. Available in: http://www.inmet.gov.br/portal/index.php?r=clima/mesTempo. Last accessed on: 16th March 2016.

Jesus, H.C., Fernandes, L.F.L., Zandonade, E., Anjos Jr, E.E., Gonçalves, R.F., Marques, F.C., Reis, L.A., Romano, C.T., Teixeira, R.D., Santos Sad, C.M. 2003. Avaliação da contaminação por metais pesados em caranguejos e sedimentos de áreas de manguezal do sistema estuarino de Vitória - ES. Technical Report – Project Facitec/PMV-ES, contract number 4985717/2001, 40.

Kirimurê Institute. 2013. Baía de Todos os Santos. Available in: <http://www.btsinstitutokirimure.ufba.br/?p=4>. Last accessed: 6th June 2013.

Marchand C., Allenbach M., Lallier-Vergès E. 2011. Relationships between heavy metals distribution and organic matter cycling in mangrove sediments (Conception Bay, New Caledonia). *Geoderma*, **160**:444-456. Doi:10.1016/j.geoderma.2010.10.015

Milazzo A.D.D., Silva A.C.M., De Oliveira D.A.F., Cruz M.J.M. 2014. The influence of seasonality (dry and rainy) on the bioavailability and bioconcentration of metals in an estuarine zone. *Estuarine, Coastal and Shelf Science*, **149**:143-150. Doi: http://dx.doi.org/10.1016/j.ecss.2014.08.013

Nazir R., Khan M., Masab M., Rehman H.U., Rauf N.U., Shahab S., Ameer N., Sajed M., Ullah M., Rafeeq M., Shaheen Z. 2015. Accumulation of heavy metals (Ni, Cu, Cd, Cr, Pb, Zn, Fe) in the soil, water and plants and analysis of physico-chemical parameters of soil and water collected from Tanda Dam Kohat. *Journal of Pharmaceutical Sciences and Research*, **7**(3):89-97.

Niyogi S. & Wood C.M. 2004. Biotic ligand model, a flexible tool of developing site-specific water quality guidelines for metals. *Environmental Science & Technology*, **38**(23):6177-6192. Doi: 10.1021/es0496524

Nizoli E.C. & Luiz-Silva W. 2009. O papel dos sulfetos volatilizados por acidificação no controle do potencial de biodisponibilidade de metais em sedimentos contaminados de um estuário tropical, no sudeste do Brasil. *Química Nova*, **32**(2):365–372. Doi: http://dx.doi.org/10.1590/S0100-40422009000200018

Otero O.M.F., Barbosa R.M., Queiroz A.F. de S., Castro A.M. de, Mâcedo B.L.F. 2008. Valores de referência para metais traço nos sedimentos de manguezais da Baía de Todos os Santos. In: Queiroz, Antônio Fernando de Souza & Celino Joil José. Avaliação de Ambientes na Baía de Todos os Santos: Aspectos geoquímicos, geofísicos e biológicos. Salvador, UFBA, 101 - 114 p.

Queiroz A.F. de S. & Celino J.J. 2008. Manguezais e ecossistemas estuarinos da Baía de Todos os Santos. In: Queiroz, Antônio Fernando de Souza & Celino Joil José. Avaliação de Ambientes na

Baía de Todos os Santos: Aspectos geoquímicos, geofísicos e biológicos. Salvador, UFBA, 39 - 58 p.

Regnier P., Arndt S., Goossens N., Volta C., Laruelle G.G., Lauerwald R., Hartmann J. 2013. Modelling estuarine biochemical dynamics: from the local to the global scale. *Aquatic Geochemistry*, **19**:591-626. Doi: 10.1007/s10498-013-9218-3

Reitermajer D., Celino J.J., Queiroz A.F. de S. 2011. Heavy metal distribution in the sediment profiles of the Sauípe River Estuary, north seashore of the Bahia State, Brazil. *Microchemical Journal*, **99**:400–405. Doi: http://dx.doi.org/10.1016/j.microc.2011.06.015

Van Gestel C.A.M. & Koolhaas J.E. 2004. Water-extractability, free ion activity, and pH explain cadmium sorption and toxicity to Folsomia Candida (Collembola) in seven soil-pH combinations. *Environmental Toxicology and Chemistry*, **23**(8):1822-1833.