Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
3 (3): 187-193. July-September, 2018
doi: 10.12957/jse.2018.38136

JSE
RESEARCH PAPER

URBAN SANITARY CONDITIONS AND BATHING WATER QUALITY OF THE ENSEADA AND SÃO LOURENÇO BEACHES, MUNICIPALITY OF BERTIOGA, SÃO PAULO (SE, BRAZIL)

Renata Aparecida Costa[1]*, Antonio Roberto Saad[2], Anderson Targino da Silva Ferreira[1], Maria Carolina Hernandez Ribeiro[3] And Regina de Oliveira Moraes Arruda[1]

1 Universidade Guarulhos, Mestrado em Análise Geoambiental Guarulhos, São Paulo, Brazil

2 Universidade de São Paulo, Instituto de Geociências, IGc/USP, São Paulo, SP, Brazil

3 Universidade de São Paulo, Escola de Artes, Ciências e Humanidades, EACH/USP, Programa de Pós-Graduação em Sustentabilidade, São Paulo, Brazil

* Corresponding author, costa-ra@hotmail.com

Received on 26 August 2018
Received in revised form on 18 September 2018
Accepted on 22 September 2018

Editor: Maria Virgínia Alves Martins, Universidade do Estado do Rio de Janeiro, Brazil

Citation:

Costa, R.A., Saad, A.R., Ferreira, A.T.S., Ribeiro, M.C.H., Arruda, R.O.M., 2018. Urban sanitary conditions and bathing water quality of the Enseada and São Lourenço Beaches, Municipality of Bertioga, São Paulo (SE, Brazil). Journal of Sedimentary Environments, 3 (3): 187-196.

Abstract

Brazilian coastal zone comprises more than 8,000 km of extension, which together with the tropical climate, increase the interest of the coastal tourism in the coastal zone. Consequently, the demand for services in coastal cities, such as basic sanitation, is also increasing. In this way, the evaluation of the beach waters quality is of great relevance, since the contact with contaminated water can raise the exposure to pathogenic microorganisms and with this the transmission of waterborne diseases. The objective of this study was to evaluate the balneability of two beaches (Enseada and São Lourenço, municipality of Bertioga, São Paulo State, SP, Brazil) using sanitary conditions as indicators. The soil coverture and sanitary sewage system were related to the quality of the beach waters. For the analyzed period (2010 to 2016) a direct correlation ($R = 0.58$ and $R = 0.46$) was observed between the monitoring stations balneability using the criteria of the "Conselho Nacional do Meio Ambiente" (National Council of the Environment) CONAMA 274/2000 and the World Health Organization, respectively, and the index of the sanitary sewage system for the region, similarly, the coefficient of determination (R^2) presented values of 0.34 and 0.21. The results of the applied methodology allowed a satisfactory evaluation of the water quality of selected beaches and suggested that the São Lourenço beach has a better sanitary sewage system and, consequently, a better bathing water quality and lower risks to the bathers health, while the Enseada Beach presented regular indices due to the lack of a sewage collection system in most of this settlement area.

Keywords: Land Use and Occupation. Depletion of Sanitary System. Balneability.

1. Introduction

The Brazilian coast, bounded by the Atlantic Ocean, has an extension of more than 8,000 Km. It is considered one of the largest and most beautiful coasts in the world. It is an environmentally sensitive region due to the presence of mangroves, barrier islands, sandy spits, beaches and estuaries (Suguio, 2003). However, it also arouses economic interests such as the development of large industrial complexes, ports, oil exploration, tourism, among others, associated with an intense urban expansion, which includes important Brazilian capital cities (Lisboa and Luz, 2012).

Due to Brazilian tropical climate, characterized by hot summers and mild winters (Nimer, 1989), the use of beaches both by locals and tourists occurs throughout the year. Therefore, the recreation practices (i.e. swimming, diving and water sports; CETESB, 2010-2017) present a great appeal for most users and, thus, there is an increase of beach tourism (Ruschmann, 1997), tourism of the second residence, and consequently the floating population growth at the littoral.

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
3 (3): 187-193. July-September, 2018
doi: 10.12957/jse.2018.38136

These factors are reflected on the seasonal overload of natural resources and public services, like sanitation, among others socio-environmental imbalances (Assis, 2003).

Due to human occupation, the coastal marine environment becomes the final recipient of several products of anthropogenic origin, coming from rivers or the mainland and/or from urban storm drains, whose effluents end up in the sea (Costa et al., 2016). The most common anthropogenic impacts in coastal areas are related to the increase of organic suply, from sewage disposal in urban drainage, which compromises the water quality (Tucci, 2010). Therefore, there is a direct impact on the seawater quality, which can lead to health problems for bathers.

In this context, this work presents a methodological proposal that allows to evaluate the sanitary conditions of the urban areas. They are correlated with the balneability indexes proposed by the "Conselho Nacional do Meio Ambiente" (National Council of the Environment; CONAMA), through CONAMA 274/2000 resolution.

As a case study, the Enseada and São Lourenço beaches were chosen (Fig. 1). Both study areas make part of a touristic resort located in the Bertioga city, São Paulo State (SE, Brazil). The sanitary conditions in this area were monitored by the "Companhia Ambiental do Estado de São Paulo" (Environmental Company of São Paulo State; CETESB).

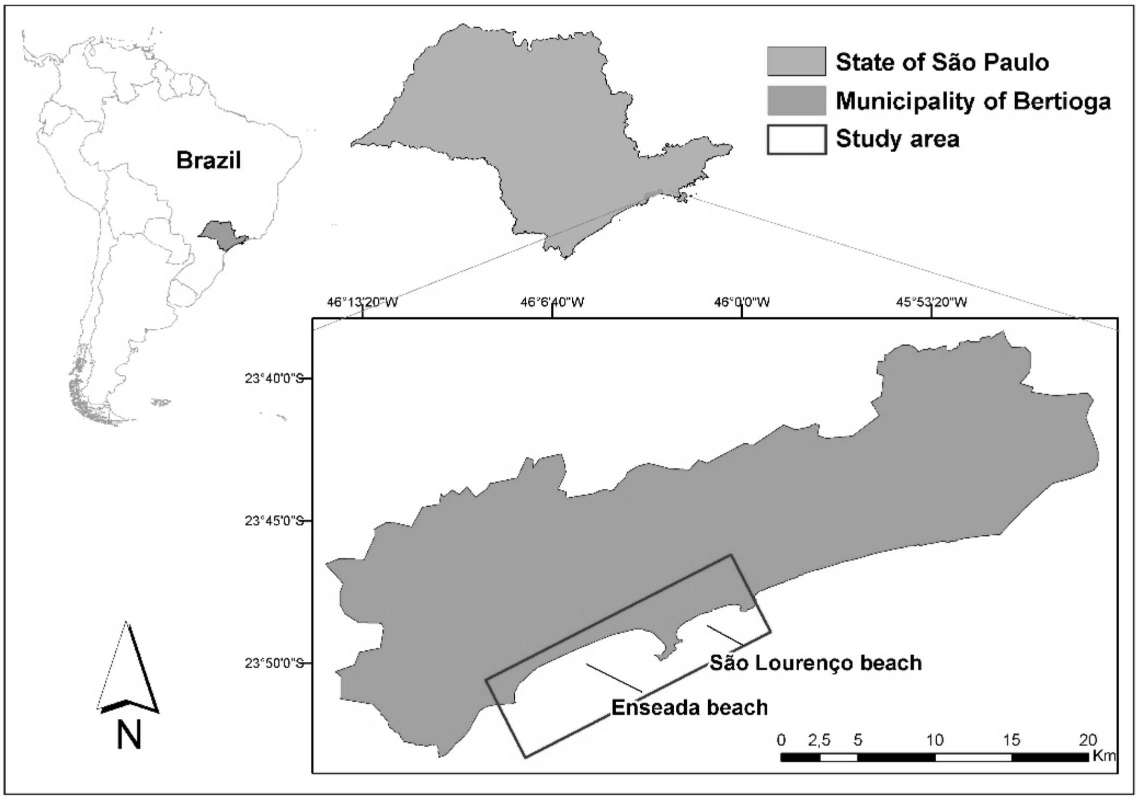

Fig. 1. Location of the study area.

2. Study area

Bertioga is located in São Paulo State (SE Brazil), about 100 km from the São Paulo city, and is one of the nine cities that belong to the Baixada Santista Metropolitan Region (BSMR). It has an area of 491,546 km² and estimated population of ≈59,297 inhabitants (IBGE, 2018). According to data from the municipal government of Bertioga (PMB, 2016), in 2000 and 2010 there were ≈26,149 and 44,834 households, respectively, 62% of which were occasional users which use theses beaches as a second residential area during the weekends, holidays and vacations.

The Bertioga climate is subtropical humid, with hot summers (average temperature ≈30°C) and relatively cold winters (average temperature ≈17°C), with average annual precipitation of ≈3128mm (DAEE, 2018). According to Rossi and Queiroz Neto (2002), there is no defined dry season, but the annual rainfall distribution reveals a strong concentration of rainfall in the summer months (January to March), while the lowest rainfall occurs in the winter period.

Bertioga region has about 30 km of coastline divided into 5 beaches, used for several sports highly searched by tourists as it contemplates privileged Nature located near the Serra do Mar, with protected green area, such as Serra do Mar Park and Restinga de Bertioga, covering 72% of this region (SELT, 2010; POLIS, 2013). This coastal region has, in general, wave-induced tides and currents, whose predominant direction is E-SE on the ebb and W-NW in the flood tide (Harari and Camargo, 1998; Harari et al., 2006).

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
3 (3): 187-193. July-September, 2018
doi: 10.12957/jse.2018.38136

3. Balneability and Influence Factors

Balneability is the qualification of waters destined to recreation, that can be used for leisure (bathers) or aquatic sports (swimming, diving, among others); in this case the first contact with water can take place for long periods with great possibility of ingestion. Secondary contact occurs when the contact time is not long or when this it is sporadic or accidental, with a small possibility of ingestion, for example, in fishing and navigation (CETESB, 2010-2017).

The bathing water quality is mostly determined, based on the number of bacteria related to fecal contamination present in waters intended for primary recreation contact (CETESB, 2010-2017). Thus, there are some factors that may contribute to the increase of bacterial levels or favor bacterial decay.

One of the main influences for increasing fecal water contamination is the lack of collection and disposal of effluents. In places without this service there is a greater possibility of organic material is released directly into streams, rivers or drainage canals and consequently, flow into the sea. This factor can be aggravated by the occupation density, determining a greater pollutant load (Hirai, 2014). The floating population contributes to the deterioration of the bathing water quality and significantly increasing the sewage generation (CETESB, 2010-2017).

The rainfall occurrence can determine the bad bathing water quality. Rainwater may quickly carry solid wastes and animal feces existing in the streets and transport the sewage dumped irregularly into drainage channels, rivers, and streams towards the sea, contaminating salt-waters. Rainfall can also lead to the leakage of septic tanks, leading wastewater to drainage channels, whose final destination will be the sea (IAP, 2016).

The solar radiance plays a fundamental role in bacterial decay, that is, the higher incidence of ultraviolet rays will lead to greater bacterial decay. This factor is linked to the water turbidity because the larger particles amount in suspension, reduces the solar penetration. Wave height and sediment type contribute to a greater or less water turbidity (Aragonés et al., 2016). In coves or bays, the contamination by streams launched at sea can make the pollution excessive, since the dilution becomes impaired by the small intensity of currents (Natal et al., 2005). Tidal conditions may contribute as a positive or negative factor for bathing. The flood tide, due to the large volume of water, makes difficult to drain the contaminated effluents entering the system but favors their dilution; on the other hand, the ebb tide drains the contaminated wastewater effluents reducing its influence in the system (CETESB, 2010-2017).

4. Material and Methods

4.1 Data on balneability and rainfall

CETESB is the entity responsible for monitoring the São Paulo beaches in accordance with criteria established by the CONAMA 274/2000 resolution. The collections are carried out in consecutive weeks, at a depth of 1 meter, at which most bathers remain.

For the period 2010-2016, weekly data of bathing water quality (*Enterococcus* contents) were collected by CETESB at Enseada and São Lourenço beachs. These results are reported in the Quality Reports of Beaches and Coastal Waters of São Paulo State. These data are annually available at the website https://cetesb.sp.gov.br/ (CETESB, 2010-2017). Four collection stations were analyzed at Enseada Beach and two at São Lourenço Beach, close to urban drainage channels.

For the classification of bathing water, the resolution CONAMA 274/2000 presents three microbiological indicators and their limit values, resulting from analyzes made in five consecutive weeks. According to this resolution, Suitable Waters can fall into one of the following categories: 1) "Excellent" - when 80% or more of a set of samples obtained in each of the previous five weeks, taken in the same site have ≤250/100 mL of thermotolerant coliforms or ≤200/100 mL of *Escherichia coli* or ≤25/100 mL of *Enterococcus*; 2) "Very Good" - when 80% or more of a set of samples obtained in each of the previous five weeks, collected at the same site, there are ≤500/100 mL of thermotolerant coliforms or ≤400/100 mL of *Escherichia coli* or ≤50/100 mL of *Enterococcus*; 3) "Satisfactory" - when 80% or more of a set of samples obtained in each of the previous five weeks, collected at the same site, have ≤1,000/100 mL of thermotolerant coliforms or ≤800/100 mL of *Escherichia coli* or ≤100/100 mL of *Enterococcus* and; 4) "Inappropriate" if it does not meet the criteria for Suitable Waters, or if the obtained value in the last sampling is >2500/100 mL of thermotolerant coliforms or >2000/100 mL of *Escherichia coli* or >400/100 mL of *Enterococcus*. It is important to note that, according to this resolution, these standards for *Enterococcus* are only applied to marine waters,

From these weekly data, the annual bathing water quality for beaches is given as follows: 1) "Excellent" - Beaches classified as "Excellent" in 100% of the time; 2) "Good" – "Suitable" Beaches in 100% of the time, except when classified as "Excellent"; 3) "Regular" - Beaches classified as "Inappropriate" in up to 25% of the time; 4) "Bad" - Beaches classified as "Unsuitable" between 25% and 50% of the time; 5) "Unsuitable" - Beaches classified as "Unsuitable" in more than 50% of the time.

Similarly, the World Health Organization (WHO) uses its own criteria to classify recreational waters, considering the possibility of contracting possible diseases, related to gastroenteritis and acute respiratory illnesses. These values were developed in order to avoid outbreaks caused by exposure to these waters (WHO, 2003).

The WHO ranks in four classes (A, B, C, and D), based on the 95th percentile of the intestinal *Enterococcus*

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
3 (3): 187-193. July-September, 2018
doi: 10.12957/jse.2018.38136

concentration /100 mL, that is, 95% of the samples of a given period should be below a specific value, for to fit into a class (Table 1). Each class presents the risk of contracting associated diseases (WHO, 2003).

The rainfall information, daily acquired from rain station E3-040, located in the Bertioga city, São Paulo, SP, was obtained from the hydrological database of the Department of Water and Electric Energy (Departamento de Águas e Energia Elétrica, DAEE) website at http://www.daee.sp.gov.br/ (DAEE, 2018). Precipitation data were subdivided into three levels before sampling: P24 (24 hours), P48 (48 hours) and P72 (72 hours), in order to identify the influence between precipitation and the presence of *Enterococcus* (Hirai and Porto, 2016).

Tab. 1. Criteria for classification of beaches and associated risks according to WHO (2003).

Class	Percentile 95 *Enterococcus*/ 100 mL	%	Risk of contracting gastroenteritis	%	Risk of contracting feverish respiratory diseases
A	≤ 40	< 1	Less than 1 case in 100 exposures	<0.3	Insignificant
B	From 41 to 200	1 a 5	1 case in 20 exposures	0.3 to 1.9	Less than 1 case in 50 exposures
C	From 201 to 500	5 a 10	1 case between 10 up to 20 exposures	1.9 to 3.9	1 case between 25 up to 50 exposures
D	> 500	> 10	More than 10% of cases in 1 exposure	>3.9	More than 1 case in 25 exposures

The analysis of the relationship between the *Enterococcus* variables and precipitation was performed using the correlation coefficient (R) and the square of the Pearson correlation coefficient (R^2), which indicate the degree of relationship between two variables. The positive or negative, correlation coefficients, can vary between: 1.00 - absolute; 0.99 to 0.81 - very strong; 080 to 0.60 - strong; 0.59 to 0.31 - moderate; 0.30 to 0.11 - weak; 0.10 to 0.01 - very weak, and; 0.00 - null (Montgomery et al., 2006).

4.2 Map of land cover

The mapping of the land cover was generated with the software ArcGIS 10.2, through the classification supervised by the maximum likelihood classification (MAXVER). This classifier is based on statistical criteria of mean, variance and covariance, so that the calculation estimates the probability of a pixel belonging to a predefined class (training samples) (Jensen, 2005). The training samples were representative of the 17 types of soil geometric pattern, as well as their combination, according to Stewart and Oke (2012). These were based on the multispectral orbital images corresponding to the Landsat-8 satellite infrared visible bands for the scenario of September 23, 2017, with coordinates 219/076 for their point and orbit (USGS, 2018).

The accuracy evaluation of the land cover map classification was performed using the analytical technique of the kappa index (k, Equation 1), which, from reference areas (n) randomly distributed in the image, calculates the difference measure and the likelihood of agreement between reference values and that of the classification (Congalton and Green, 2009).

As reference areas, 50 polygons (Congalton, 1991), representative of this class, were observed in the high spatial resolution images of the Google Earth Pro software (Ferreira et al., 2017).

$$k = N \sum X_{ii} - \sum X_{i+} X_{+i} / N^2 - \sum X_{i+} X_{+i} \qquad \text{(Equation 1)}$$

Where, X_{ii} is the observed agreement; X_{i+} and X_{+i} (marginal product) is the expected agreement, and N is the total observed element.

4.3 Index of health conditions

For the general analysis of the urban sanitary conditions of the municipality of Bertioga, a map of the Sanitary Sewage Quality Index ($INDEX_{ESG}$) was performed according to the following parameters: households connected to the General Sewage or Rainwater Network (RGE); households that launch sewage in river, lake or sea; (ERLM); households that launch sewage in ditch (EVV); households with rudimentary pit sewage (EFR) and; households that launch sewage in septic tank (EFS). The information from the Information Base of the 2010 Demographic Census: Results of the Universe by Census Sector of the Brazilian Institute of Geography and Statistics was used (Instituto Brasileiro de Geografia e Estatística; IBGE, 2011).

The standardization of thematic maps was done through the definition of indicators in intervals between zero and one (Equation 2). For the better condition, the value is closer to 1 (one) and, for the worse one, the value is closer to 0 (zero).

$$I = \frac{(\text{Observed Value} - \text{Worst Value})}{(\text{Best Value} - \text{Worst Value})} \qquad \text{(Equation 2)}$$

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
3 (3): 187-193. July-September, 2018
doi: 10.12957/jse.2018.38136

RESEARCH PAPER

The best value is the expected maximum value (1 - one) for each indicator. While the worst value is the minimum possible value (0 - zero). The weighting of the factors that compose this index was made through the Hierarchical Analysis Process (PAH), according to Saaty (2008) weighing scale and with their respective consistency rates (acceptable <0.10). Thus, these weights ranged in importance from 1 - 9, for the most important, and from 1/3 - 1/9 to the less important ones (Table 2). The choice of weights considered the relative importance of each parameter with a negative influence on bathing. After that, the resulting weights were applied to the variables by means of Equation 3 (General Index of Quality of Sanitary Sewage - $INDEX_{ESG}$):

$$INDEX_{ESG} = RGE * 0.50 + EVV * 0.26 + ERLM * 0.13 + EFR * 0.07 + EFS * 0.03 \quad \text{(Equation 3)}$$

Where: $INDEX_{ESG}$ - Index of Sanitary Exhaustion; RGE - households linked to the general sewage or rainwater network; EVV - households with sewage in the ditch; ERLM - households that launch sewage in river, lake or sea; EFR - households with rudimentary pit sewage; EFS - households that launch sewage in a septic tank.

Finally, the results of the index of health conditions were classified according to the following intervals: very bad from 0.00 to 0.20; bad from 0.21 to 0.40; regular from 0.41 to 0.60; good from 0.61 to 0.80 and; optimal from 0.81 to 1.00.

Tab. 2. Saaty (2008) weighing scale applied in the Analytical Process of Hierarchy to obtain the relative importance of the physical variables.

1/9	1/7	1/5	1/3	1	3	5	7	9
Extreme	Very strong	Strong	Moderate	Equal	Moderate	Strong	Very Strong	Extreme
Less important					Most important			

5. Results and Discussion

5.1 Map of the land cover

In Figure 2, it is possible to observe that the dense forest predominates in most of the municipality of Bertioga. The urban area for Enseada beach is limited between the coastal shoreline and the Itapanhaú river, whereas for the São Lourenço beach, the limit of occupation is given by the Rio-Santos Highway (SP-55/101) and the coastal shoreline.

Among the classes of buildings, there was a predominance of the "compact low rise" class in Enseada Beach, according to the classification of Stewart and Oke (2012), with buildings from 1 to 3 floors, eventually up to 25 meters high, distributed compactly. At the São Lourenço beach, "open high rise" and "open low rise" buildings predominated, with buildings measuring ≥25 meters high, spaced near the edge and constructions of 1 to 3 floors, possibly with up to 25 meters high, spaced in the other occupied urban area (Fig. 2).

According to Ariza et al. (2008), the urban areas of the studied beaches fall into the semi-urban category, with about 32% of their built urban area, with low-density of residential and commercial areas. As for the recreational function of the beach, as well as water quality, these beaches are generally less polluted when compared to the urban beaches (Ariza et al., 2010).

5.2 Conditions of sanitary sewage and bathing

The maps of sanitary conditions were composed of the main types of the sanitary sewage system and their respective weights. Thus, it was possible to observe that the best indices were recorded in areas whose households were covered by the four sewage treatment plants (STPs) operating in the area.

Two of these stations (STP Bertioga and STP Vista Linda) are managed by the Companhia de Saneamento Básico do Estado de São Paulo (SABESP; Basic Sanitation Company of São Paulo State) and two others (STP Riviera and STP Sesc) managed by private entities, respectively: Riviera of São Lourenço condominium and Ruy Fonseca vacation colony.

Thus, in the maps of Figure 3, the areas with the best indices are those related to the households connected to the general sewage collection network, and the soil cover related to the "open high rise" class (Fig. 3a), which are served by effluent treatment plants. According to the Municipal Basic Sanitation Plan (PMSB), those central and/or commercial sectors (classes "compact low rise" and "open low rise"; Fig. 2a, b), corresponded to ≈23% in 2010 and ≈53% in 2016 of the areas attended by the sewage collection service (Bertioga, 2010, 2017).

For the areas whose indexes presented very bad or poor quality (<0.21; maps of Fig. 3 a-f), the main problem was related to a large proportion of households whose waste was discarded into septic, rudimentary ditch, open pit or water body (rivers, streams or sea). In these zones, the main forms of occupation belonged to the "compact low rise" class, located mainly in the north-central and south-west part of the urban area, whose average family income is lower than that of families located near the seafront (IBGE, 2011). Considering that the areas adjacent to the collection stations 1 to 6, classified by the CETESB bathing parameters as Good, Regular and Excellent, respectively, it was possible to match these average data and WHO data for the period 2010 to 2016, with the $INDEX_{ESG}$ results presented in the map of Fig. 3f.

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
3 (3): 187-193. July-September, 2018
doi: 10.12957/jse.2018.38136

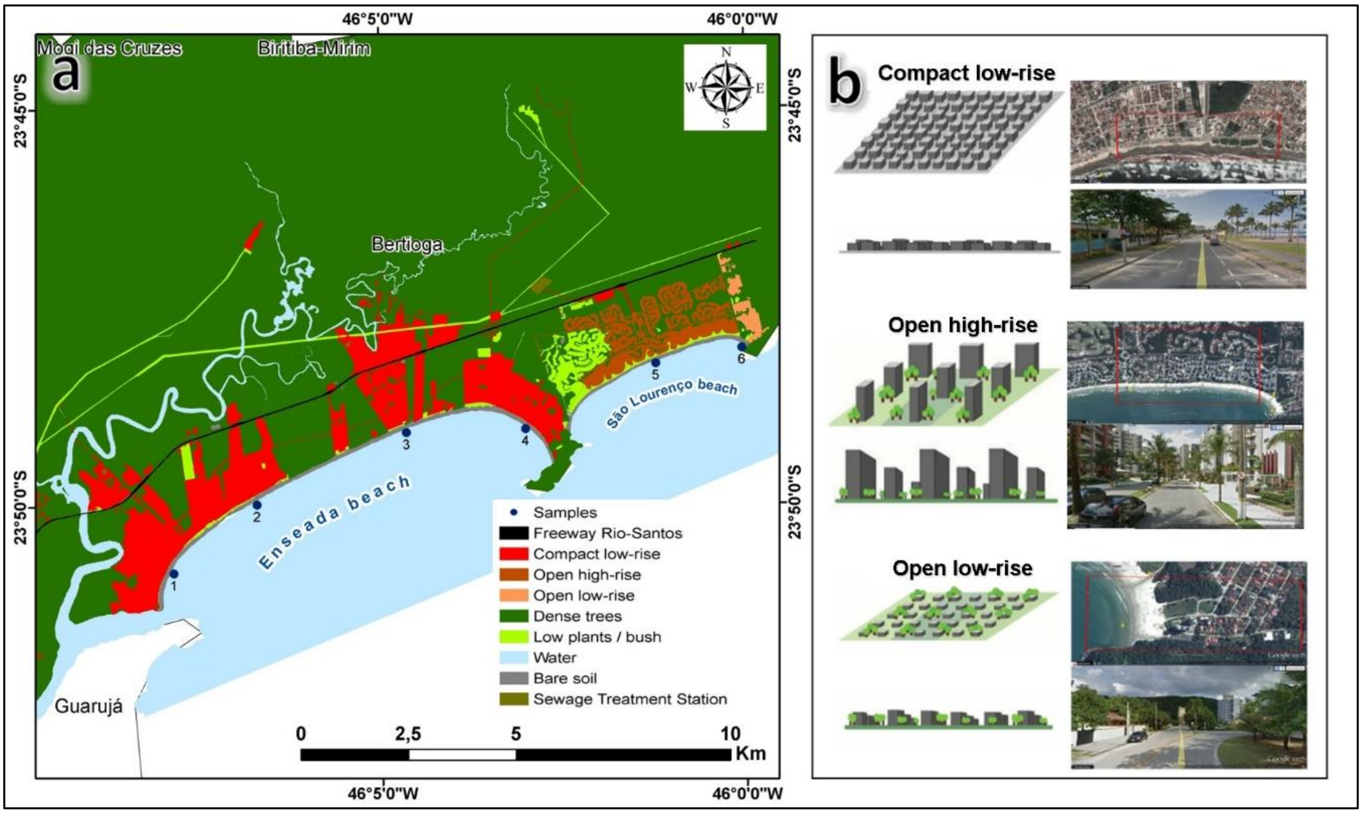

Fig. 2. (a) Land cover map of the study area with sampling and monitoring stations 1 to 6. (b) Examples of land cover classes in urban areas according to Stewart and Oke (2012) and Google Earth (2017), as well as their perspectives (oblique and frontal).

Thus, a direct correlation (R = 0.58 and R = 0.46) was recorded in the sampling stations between the monitoring results of the bathing water quality (CETESB and WHO) and $INDEX_{ESG}$ (Fig. 3f). Similarly, the coefficient of determination (R^2) presented values of 0.34 and 0.21, respectively. This means that based on CETESB classification, 34% of water quality variability can be explained by the sanitary conditions. Based on the WHO classification this value is 21%.

Another factor that influences the bathing water quality, as well as the increase or not of the *Enterococcus* values, was the relation of these parameters to the rainfall. For the monitored stations, it was possible to observe a moderate correlation (R = 0.45) between the average data of bathing water and the rainfall that fell, 24 hours before the collection day, for all the analyzed years. Strong correlations (R = 0.60 to 0.69) could be observed between 2011 and 2016, for all stations (Table 3).

These high values of correlations observed in Table 3, corroborate the Griffith et al. (2010) statements. These authors point out that the highest frequencies of bacterial concentrations in marine waters occur within 24 hours following precipitation events, especially when intense rains occur and close to the places where drains are flowing towards the sea. These values decline over the next three days.

Similarly, Ackerman and Weisberg (2003) stated that there is a greater correlation between rainfall and bacteria concentrations in marine waters when rainfall levels are >25 mm. These authors observed that the significant increase of bacteria density occurs on the day after precipitation. Zhang et al. (2013) pointed out that in places with frequent rainfall, such as the studied areas, depending on the accumulation of previous rainfall and high concentrations of bacteria, water quality cannot recover before a new rainfall process; which means it remains degraded. In such cases, the time required to improve water quality depends on the intensity and rainfall duration.

5.3 Analysis of monitoring stations

For the analyzed period (2010-2016), in Station 1 was observed the presence of residual waters that leave the urban area and reach the marine waters. However, the balneability of this monitoring station presented an annual “Regular” evaluation in 86% of the analyzed period and 14% “Good”. In fact, during the analyzed years, occurred unsuitable periods for the sea-bathing up to 25% of the time. These periods were mainly concentrated in the summer season

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
3 (3): 187-193. July-September, 2018
doi: 10.12957/jse.2018.38136

when there is an increase in the floating population, associated with periods of higher rainfall. It should be noted that the relationship between rainfall and *Enterococcus* presented a moderate correlation most of the time, with mean value of 0.45 for the 24 hours prior to the sample collection (Table 3).

Station 2 presented an annual "Regular" balneability in 86% of the analyzed period and "Good" in 14% of the time. With periods of "Unsuitable" to the bath up to 23% of the time. It should be noted that the relationship between rainfall and *Enterococcus* presented a moderate correlation most of the time, with mean value of 0.50 (Table 3).

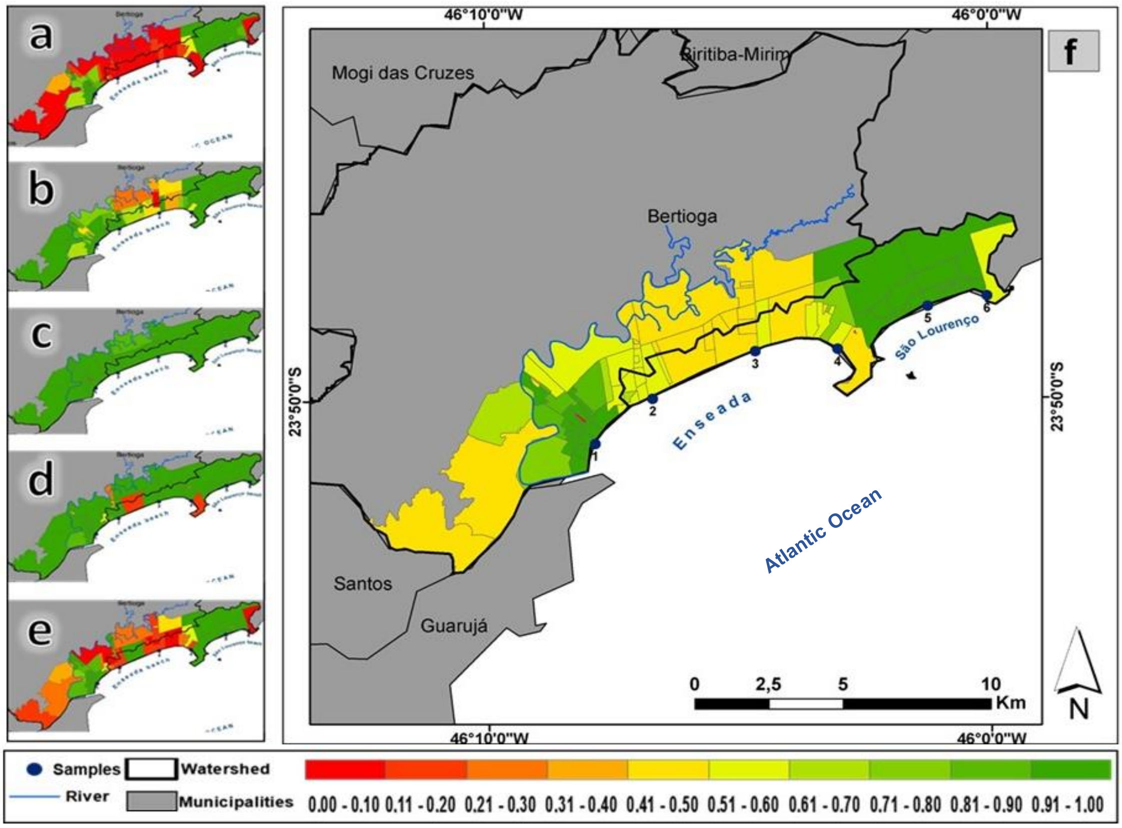

Fig. 3. Maps of the Quality Index of Sanitary Sewage ($INDEX_{ESG}$): (a) sewage connected to the general network; (b) sewage conditions through the open pit; (c) sewage conditions via river, lake or sea; (d) rudimentary pit conditions; (e) septic tank conditions; (f) General Index of Sanitary Sewage Quality in the study area. The indices vary from 0 to 1, with 0 being the worst situation (red color) and 1 being the best situation illustrated by the green color in the elaborated maps. Monitoring stations 1 to 6.

For Station 3, the annual assessment of bathing was "Regular" in 71% and "Good" in 29% of the analyzed time. The greatest periods of impropriety occurred in 2012 and 2013, with percentages of 17% and 25%, respectively. The relationship between rainfall and *Enterococcus* presented a moderate correlation, with a mean value of 0.49 (Table 3).

Station 4 was the only one that presented an annual "Bad" evaluation, with 29% of the period of interdiction to the bath in 2013 and 14% in the other years. "Regular" and "Good" evaluations were observed respectively in 57% and 29% of the time. Thus, the highest percentages of "Unsuitable" to the bath were recorded in the rainy season, suggesting a relationship between floating population (vacation period) and precipitation.

For the Station 4, the correlations between the amount of rainfall and *Enterococcus* presented a mean value of 0.44 (moderate), in the analyzed period. However, the highest correlation (0.69) was observed in 2013 (Table 3). Regarding the public health assessment, based on WHO criteria (2003), the results indicate for the first four stations, a risk ranging from 1% to 10% of users get gastroenteritis-related diseases and from 0.3% to 3.9% of respiratory infections.

Station 5 had its annual bathing qualification classified as "Good" (71%) and "Regular" (29%), with periods of interdiction to the bath in only 4% of the time for the year 2011 and 2% for the year 2012. Regarding the public health assessment (WHO, 2003), this station presented a few moments of "Unsuitable" conditions related to periods of short and long vacations. This suggests that good conditions are related to the type of environmental management practiced near this station, where the households have 100% of their effluents collected and treated (Costa et al., 2016).

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
3 (3): 187-193. July-September, 2018
doi: 10.12957/jse.2018.38136

Tab. 3. Pearson correlation coefficient (R) between the cumulative rainfall variables and the *Enterococcus* contents, with precipitation 24h before sampling in the monitoring stations indicated in Figures 2a and 3f.

Sampling Stations	2010	2011	2012	2013	2014	2015	2016	Mean	
1	0.45	0.43	0.40	0.39	0.41	0.45	0.61	0.45	0.45
2	0.57	0.53	0.40	0.62	0.55	0.47	0.36	0.50	
3	0.48	0.52	0.43	0.50	0.59	0.33	0.60	0.49	
4	0.52	0.53	0.30	0.69	0.55	0.26	0.24	0.44	
5	0.47	0.57	0.64	0.40	0.49	0.03	0.37	0.42	
6	0.47	0.69	0.39	0.33	0.13	0.06	0.62	0.38	

Lastly, Station 6 had "Regular" bathing conditions in 43% and "Good" in 57% of the time between 2010 and 2014. During the analyzed period, the highest percentage of "Unsuitable" conditions for bath (19%) occurred in 2013. In this station, the correlation between rainfall and *Enterococcus* ranged from strong and weak, with a mean of 0.38 (Table 3). So, for public health, the possibility of contracting waterborne diseases over the analyzed years indicates a risk ranging from 1% to 5% for users to get gastroenteritis-related diseases and from 0.3% to 1.9% to have respiratory infections, except for 2013, whose risks ranged from 5% to 10% and 1.9% to 3.9%, respectively, for diseases related to gastroenteritis and respiratory infections.

6. Conclusion

The evaluation of the bathing water quality is an important issue in terms of public health, because contaminated water, mainly with sewage, puts the health of bathers at risk, and they can contract diseases such as gastroenteritis, skin diseases, among others. The present study found that some factors may have a strong influence on water quality.

The results of this work evidence that within a 24-hour period, especially in areas where adequate sewage collection and treatment is not available, there is a correlation between rainfall and an increase in bacterial levels, what makes the water "Unsuitable" to the bath. They also show that in areas where there is qualified environmental management, which includes sewage collection and treatment and planning urbanization, the bathing water quality is good.

Acknowledgment

The authors thank the SER Educational Group for the provided infrastructure, the Master Program in Geoenvironmental Analysis (Análise Geoambiental), the Geoprocessing Laboratory of Universidade Guarulhos (Lab. GEOPRO-UNG) and the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, Brazil (CAPES; Financing Code 001).

References

Ackerman, D., Weisberg, S.B., 2003. Relationship between rainfall and beach bacterial concentrations on Santa Monica Bay beaches. Journal of Water and Health 1 (2), 85-89.

Aragonés, L., López, I., Palazón, A., López-Úbeda, R., García, C., 2016. Evaluation of the quality of coastal bathing waters in Spain through fecal bacteria *Escherichia coli* and *Enterococcus*. Science of the Total Environment 566-567, 288-297.

Ariza, E., Jiménez, J.A., Sardá, R.A., 2008. Critical assessment of beach management on the Catalan coast. Ocean & Coastal Management 51 (2), 141-160. https://doi.org/10.1016/j.ocecoaman. 2007.02.009

Ariza, E., Jimenez, J.A., Sarda, R., Villares, M., Pinto, J., Fraguell, R., Roca, E., Marti, C., Valdemoro, H., Ballester, R., Fluvia, M., 2010. Proposal for an integral quality for urban and urbanized beaches. Environmental Management 45 (5), 998-1013. https://doi.org/10.1007/s00267-010-9472-8

Assis, L. F., 2003. Turismo de segunda residência: a expressão espacial do fenômeno e as possibilidades de análise geográfica. Revista Território - Rio de Janeiro, ano VII, 11-12-13, 107-122.

Bertioga, Plano de Saneamento Básico do Município de Bertioga 2010. http://www.saneamento.sp.gov.br/pms/ugrhi07/pms_bertioga.pdf. Access: 21.01.2018.

Bertioga, Plano de Saneamento Básico do Município de Bertioga, 2017. http://www.bertioga.sp.gov.br/wp-content/uploads/2017/11/Plano-Municipal-de-Saneamento.pdf. Access: 21.01.2018.

CONAMA 274/2000, de 29 de Novembro de 2000, Conselho Nacional do Meio Ambiente, Ministério do Meio Ambiente, 2000. Define os critérios de balneabilidade em águas brasileiras. Diário Oficial da União: República Federativa do Brasil, Poder Executivo, Brasília, DF, nº 18 de 25 de Janeiro de 2001, Seção 1, páginas 70 - 71. http://www2.mma.gov.br/port/conama/legiabre.cfm?codlegi=272

CETESB, Companhia Ambiental do Estado de São Paulo: Relatório de Qualidade das Praias no Estado de São Paulo, 2010-2017. São Paulo: http://cetesb.sp.gov.br/praias/publicacoes-relatorios/. Access: 30.05.2018.

Congalton, R.A., 1991. Review of Assessing the Accuracy of Classifications of Remotely Sensed Data. Remote Sensing of Environment 37 (1), 35-46.

Congalton, R., Green, K., 2009. Assessing the Accuracy of Remotely Sensed Data. 2nd ed. Boca Raton: CRC Press.

Costa, R.A., Saad, A.R., Vargas, R.R., Dalmas, F.B., 2016. A Gestão Ambiental Aplicada ao Condomínio Riviera de São Lourenço,

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
3 (3): 187-193. July-September, 2018
doi: 10.12957/jse.2018.38136

Município de Bertioga - SP, e seus Reflexos no Índice de Balneabilidade da Praia de São Lourenço. Revista Geociências - UNG 15 (1), 94-109.

DAEE, Departamento de Águas e Energia Elétrica, 2018. http://www.daee.sp.gov.br/. Access: 30.05.2018.

Ferreira, L.S., Prata-Shimomura, A.R., Ferreira, A.T.S., Duarte, H.S.D., 2017. Mapping local climate zones for São Paulo Metropolitan Region: a comparison between the local climate zone map and two other local maps. In: Passive Low Energy Architecture. Edinburgh, Escócia, PLEA, v. II, pp 255-262.

Griffith, J.F., Schiff, K.C., Lyon, G.S., Fuhrman, J.A., 2010. Microbiological water quality at non-human influenced reference beaches in southern California during wet weather. Marine Pollution Bulletin 60 (4), 500-508.

Google Earth., 2017. Imagens de Satélite. EUA.

Harari, J., Camargo, R., 1998. Modelagem numérica da região costeira de Santos (SP): circulação de maré. Revista Brasileira de Oceanografia 46 (2), 135-156.

Harari, J., Camargo, R., França, C.A.S., Mesquita, A.R., Picarelli, S.S., 2006. Numerical modeling of the hydrodynamics in the coastal area of Sao Paulo State - Brazil. Journal of Coastal Research 39, 1560-1563.

Hirai, F.M., 2014. Metodologias de Previsão de Balneabilidade e sua Aplicação na Gestão da Qualidade da Água Destinada à Recreação. RBRH - Revista Brasileira de Recursos Hídricos 19 (3), 339-345.

Hirai, F.M., Porto, M.F.A., 2016. O desenvolvimento de ferramentas de predição de balneabilidade baseadas em níveis de precipitação: estudo de caso da praia de Cachoeira das Emas (SP). Engenharia Sanitária e Ambiental 21 (4), 797-806.

IAP, Instituto Ambiental do Paraná, 2016. http://www.iap.pr.gov.br/modules/conteudo/conteudo.php?conteudo=297. Access: 06.11. 2016.

IBGE Instituto Brasileiro de Geografia e Estatística, 2018. https://cidades.ibge.gov.br/brasil/sp/bertioga/panorama. Access: 18.01.2018.

IBGE Instituto Brasileiro de Geografia e Estatística, 2011. Base de informações do Censo Demográfico 2010: Resultados do Universo por setor censitário. Rio de Janeiro: IBGE.

Jensen, J.R., 2005. Introductory Digital Image Processing: A Remote Sensing Perspective. 3rd Ed., Upper Saddle River: Prenice Hall, Inc.

Lisboa, W.T., Luz, T.F., 2012. Mar D'ouro? Da expansão do porto à centralidade do Pré-Sal: Estratégias comunicativas no mercado emergente da Baixada Santista. Comunicologia 5 (2), 46-70.

Montgomery, D. C., Peck, E. A., Vining, G. G., 2006. Introduction to linear regression analysis, 3nd ed, Wiley-Interscience.

Natal, D., Menezes, R.M.T., Mucci, J.L.N., 2005. Fundamentos da Ecologia Humana. In Philippi Jr. A. Saneamento, Saúde e Ambiente: fundamentos para um desenvolvimento sustentável. Barueri, SP.: Manole, 2005, pp. 57-86.

Nimer, E., 1989. Climatologia do Brasil. 2. ed. Rio de Janeiro: IBGE. Departamento de Recursos Naturais e Estudos Ambientais.

PMB, Prefeitura do Município Bertioga Estância Balneária SP, 2016. URL: http://www.bertioga.sp.gov.br/servicos-online/servicos-para-o-cidadao/historia/. Access: 06.11. 2016.

POLIS, Projeto Litoral Sustentável, Desenvolvimento com inclusão social: Diagnóstico Urbano Sócio Ambiental Município de Bertioga, 2013. http://litoralsustentavel.org.br/diagnostico-urbano-socioambiental-de-bertioga/. Access: 06.11.2016.

Rossi, M., Queiroz Neto, J.P., 2002. Evolução de espodossolo ferrocárbico em gleissolo háplico no planalto da Serra do Mar, rio Guaratuba SP. Revista Brasileira de Ciência do Solo 26, 407-415. http://dx.doi.org/10.1590/S0100-06832002000200014.

Ruschmann, D., 1977. Turismo e planejamento sustentável: a proteção do meio ambiente. Campinas, Editora Papirus.

Saaty, T.L., 2008. Decision making with the analytic hierarchy process. International Journal of Services Sciences 1 (1), 83-98.

SELT, Secretaria de Esporte, Lazer e Turismo do Estado de São Paulo, 2010. Praias Paulistas. São Paulo: SELT.

Stewart, I.D, Oke, T.R., 2012. Local climate zones for urban temperature studies. Bulletin of the American Meteorological Society 92, 1879-1900.

Suguio, K., 2003. Geologia Sedimentar. São Paulo, Blucher.

Tucci, C.E.M., 2010. Urbanização e Recursos Hídricos. In: Bicudo, C. E. M., Tundisi, J. G., Scheuenstuhl, M. C. B (Org.), Águas do Brasil: Análise estratégica, Instituto de Botânica, São Paulo, pp. 113-132.

USGS, United States Geological Survey / Serviço Geológico Americano, 2018. Aquisição de imagens orbitais digitais gratuitas do satélite Landsat - 8. https://earthexplorer.usgs.gov/. Access: 22.03.2018.

WHO, World Health Organization, 2003. Guidelines for safe recreational environments volume 1 coastal and fresh Waters. Geneva. World Health Organization.

Zhang, W., Wang, J., Fan, J., Gao, D., Ju, H., 2013. Effects of rainfall on microbial water quality on Qingdao No. 1 Bathing Beach, China. Marine Pollution Bulletin 66 (1-2), 185-190.