Research, Society and Development, v. 9, n. 11, e3699119280, 2020
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Influence of pluviosity and floating population on the water quality of a neotropical costal river

Influência da pluviosidade e da população flutuante na qualidade da água de um rio da costa neotropical

Influencia de la lluvia y la población flotante en la calidad del agua de un río costero neotropical

Received: 10/13/2020 | Reviewed: 10/21/2020 | Accept: 11/14/2020 | Published: 11/18/2020

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Abstract

The contamination of waterbodies is a worldwide concern due to the increasing urbanization and industrialization of the cities without good effluent management. Touristic cities can

suffer with the number of people during high seasons periods, which can lead to an elevated use of natural resources and effluents discharges. Moreover, raining seasons, either high or low, can also play an important role in contaminating waterbodies once a dilution or concentration of contaminants may take place. The present study evaluated the water quality of the Tejereba River (Guarujá, Brazil) during the high season (January) and low season (March and May) in 2018. Reduction in water quality was observed in May, a month with low pluviosity and low tourism. The integrated data analysis (PCA) showed a positive correlation between the physicochemical parameters and the month of May, in which they were negatively correlated with pluviosity and the percentage of tourists. Despite the deterioration of water quality in May, no toxicity to *Daphnia magna* was observed. Our work showed that water quality (physicochemical and microbiological parameters), during the studied months, is more related to raining seasons than to the presence of tourists in Guarujá, Brazil.
Keywords: Domestic effluents; Physicochemical parameters; Microbiological characterization; Tejereba River.

Resumo

A contaminação de corpos d'água é uma preocupação mundial devido à crescente urbanização e industrialização das cidades sem um bom gerenciamento de efluentes. As cidades turísticas podem sofrer com o número de pessoas durante os períodos de alta temporada, o que pode levar a um elevado uso de recursos naturais e lançamento de efluentes. Além disso, as estações chuvosas, sejam altas ou baixas, também podem desempenhar um papel importante na contaminação de corpos d'água, uma vez que pode ocorrer diluição ou concentração de contaminantes. O presente trabalho avaliou a qualidade da água do rio Tejereba (Guarujá, Brasil) durante os períodos turísticos de alta (janeiro) e baixa temporada, (março e maio) no ano de 2018. A redução da qualidade da água foi observada em maio, mês de baixa pluviosidade e baixo turismo. A análise integrada de dados (PCA) mostrou correlação positiva entre os parâmetros físico-químicos e o mês de maio, na qual se correlacionaram negativamente com a pluviosidade e o percentual de turistas. Apesar da deterioração da qualidade da água em maio, nenhuma toxicidade para *Daphnia magna* foi observada. Nosso trabalho mostrou que a qualidade da água (parâmetros físico-químicos e microbiológicos), nos meses estudados, está mais relacionada às estações chuvosas do que à presença de turistas na cidade de Guarujá, Brasil.
Palavras-chave: Efluentes domésticos; Parâmetros fisicoquímicos; Caracterização microbiológica; Rio Tejereba.

Resumen

La contaminación de los cuerpos del agua es una preocupación mundial debido a la creciente urbanización y industrialización de las ciudades sin una buena gestión de los efluentes. Las ciudades turísticas pueden sufrir por la cantidad de personas mientras los períodos de temporada alta, lo que puede conducir a un alto uso de los recursos naturales y descarga de efluentes. Además, las temporadas de lluvias, sean altas o bajas, también pueden jugar un papel importante en la contaminación de los cuerpos del agua, ya que pueden producirse diluciones o concentraciones de contaminantes. El presente trabajo evaluó la calidad del agua del río Tejereba (Guarujá, Brasil) durante la temporada alta (enero) y temporada baja (marzo y mayo) en 2018. La reducción de la calidad del agua se observó en mayo, un mes de escasas precipitaciones y escaso turismo. El análisis integrado de datos (PCA) mostró una correlación positiva entre los parámetros físico-químicos y el mes de mayo, en el que se correlacionaron negativamente con las precipitaciones y el porcentaje de turistas. A pesar del deterioro de la calidad del agua en mayo, no se observó toxicidad para *Daphnia magna*. Nuestro trabajo mostró que la calidad del agua (parámetros físico-químicos y microbiológicos) en los meses evaluados está más relacionada con las temporadas de lluvias que con la presencia de turistas en la ciudad de Guarujá, Brasil.

Palabras clave: Efluentes domésticos; Parámetros físico-químicos; Caracterización microbiológica; Río Tejereba.

1. Introduction

The contamination of aquatic environments has been one of the major global problems in recent decades. Although renewable, water is a finite resource (Barreto & Garcia, 2010), and the creation of public policies for its conscious use is the only way to ensure the maintenance of this commodity provided by the ecosystem. Water is the universal solvent and it is endowed with great stability (Barreto & Garcia, 2010). Due to these properties, an expressive number of elements and chemical compounds released into aquatic ecosystems – either by natural processes or by human actions– end up incorporated into the water, becoming part of the aquatic biota. Many of the compounds released into the environment can be harmful to human consumption and are associated with public health problems (Silva & Araújo, 2003). Increased urbanization and unplanned industrialization of large centers are examples that cause such degradation of water bodies.

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In addition to these two problems, some urban centers are also affected by the presence of a fluctuating population. Population increase can lead to a higher consumption of natural resources, such as water, and a higher domestic effluent production. This often overloads the sewage treatment systems present in these cities, worsening the quality of the water that receives these effluents. This contingent is significant, especially during summer and weekend holidays, and can directly influence the water quality of the region. It is noted that for some municipalities, the floating population is larger than the permanent one, that is, during periods of vacation and long holidays, the number of people in these municipalities may be doubled, causing problems in the local water supply and basic sanitation infrastructure –which were not sized for this amount of individuals (Filho, 2014). In addition, water quality may also be influenced by periods with either higher or lower precipitation, as domestic effluents may be diluted by rainwater (Coelho, 2013).

Water quality studies are important to better understand aquatic environments and plan their use, since they have a great ecological, economic and social importance. Aquatic environments contaminated with *in natura* domestic effluents may be affected by the increase in the concentration of organic compounds –such as nitrates, nitrites, phosphates, sulfates, and ammonia– from personal care and household products, such as detergents (Marotta, et al. 2008). The presence of these compounds in the aquatic environment may cause eutrophication of waterbodies, which leads to a reduction in the concentration of dissolved oxygen, and consequent loss of this water body functionality. In addition, *in natura* domestic effluents can cause great harm to human health when it comes to the presence of pathogenic bacteria (Ribeiro et al. 2010). In Brazil, the National Environment Council (CONAMA) has as its main function the preparation of resolutions that establish norms, criteria and standards related to the control and maintenance of the environment quality. Regarding water pollution control, in 2005, CONAMA established the Resolution 357, as well as its updates n° 410/2009 and n° 430/2011 and the 274/2000 resolution which provides the classification of waterbodies and environmental guidelines for their classification, as well as the conditions and standards for discharging effluents.

In this sense, the city of Guarujá, located in Brazil, has a population of about 318 thousand inhabitants (IBGE 2018), and it can reach 2.5 million people in high touristic seasons (from December to March). The city possesses a sewage treatment system with 325 km of collection networks, directing the collected effluents to 24 pumping stations, where they are concentrated and treated and then released into the sea (CETESB 2017). However, Guarujá's treatment plant has the capacity to treat an effluent flow of 1.5 m^3/s, which only covers 78% of the effluents produced by the local population. The remaining 22% of the total sewage produced is discharged without any kind of treatment into streams and springs (Roveri, 2013). This deficit may be related to the presence of irregular occupations, as well as the increase of the floating population during high seasons, causing public health problems, visual degradation and functionality loss of these environments.

Considering the above-mentioned facts, the objective of the present study was to evaluate, through a physicochemical, microbiological and toxicological analysis, the water quality of the Tejereba River, located near irregular occupation areas in the city of Guarujá, Brazil, in three different moments taking into account precipitation periods and the touristic season of the region (January, March and May of 2018).

2. Materials and Methods

2.1 Study area

The Tejereba River (23º59'01.49"S46º14'54.65"W) (Figure 1) is located in a place of large illegal occupation areas in the city of Guarujá, Brazil, with approximately 26 thousand inhabitants (IBGE, 2018). Their clandestine settlements may worsen the environmental sanitation and public health of the municipality, mainly due to the deterioration in the bathing conditions of the beaches, causing negative results for tourism and economy. (Souza & Silva 2015). The investigated River flows along 1.86 km until reaching the sea, at Enseada beach, much appreciated by bathers. Along its course, the river goes through different types of human occupations, where the riparian forest of this river no longer exists. The climate of the region is characterized by high rainfall, which can last for 220 days per year, with an average rainfall of 163mm (Minuzzi et al. 2007). The floating population in the city of Guarujá varies, on average, from 162,109 to 222,245 thousand people during high touristic seasons (SABESP, 2018).

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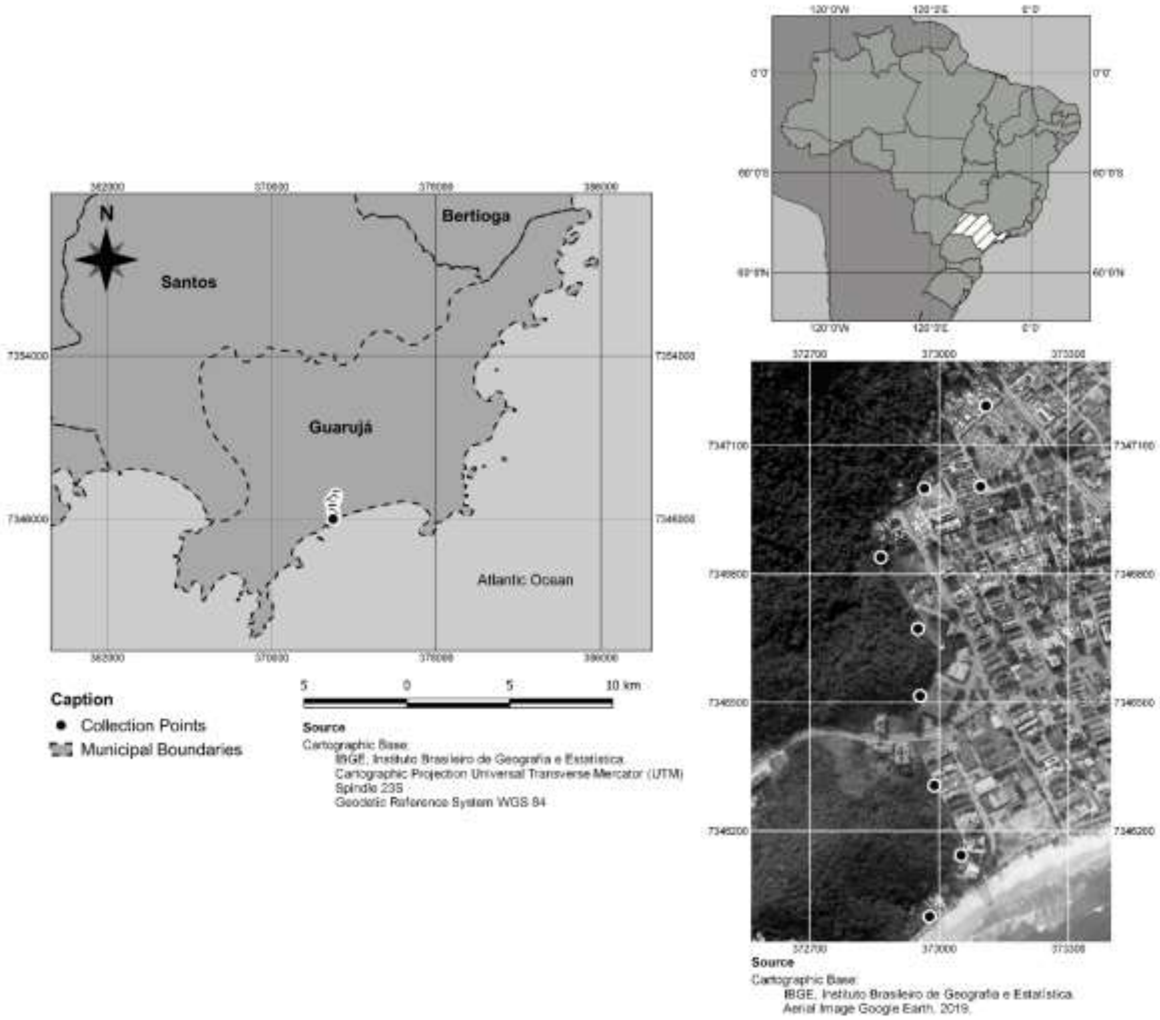
Figure 1. Map of the sites (•) in the Tejereba River (Guarujá, Brazil), where the water collection took place.



Source: Adapted from Google Earth and Google images.

2.2 Periods of water collection and sampling

The first collection in the municipality took place on January 18th, during a period of high tourism and high precipitation, with an average equal to 229 mm (Accuweather, 2018), and a floating population corresponding to 25.6% (Plano Diretor do Guarujá, 2018). The second collection took place on March 23rd, a period of low tourism and high precipitation rates, with an average equal to 129 mm (Accuweather, 2018), and a floating population of 4.8% (Plano Diretor do Guarujá, 2018). The third collection took place on May 10th, a period of low tourism and low precipitation, with an average equal to 10 mm (Accuweather, 2018), and a floating population corresponding to 4.4% (Plano Diretor do Guarujá, 2018). To

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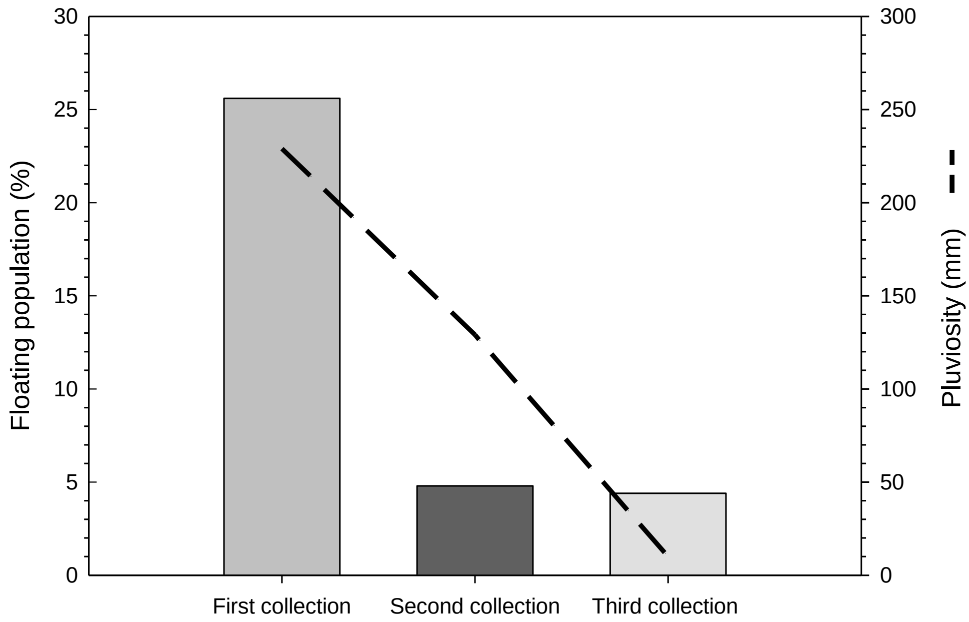
evaluate the water quality of the different points in the three collections, the physicochemical and microbiological parameters were compared with the limits established for fresh water, since the collected waters were characterized as belonging to this class (0% salinity) according to CONAMA 357/05 resolution. The river studied has a length of 1.86 km. Collections were performed every 200 meters approximately, totaling 9 points, as shown in Figure 2. Table I indicates the name of the points, their respective coordinates and the main characteristics of their surroundings.

Figure 2. High touristic season (%) and pluviosity (mm) during the first (January), second (February), and third (may) water collections in Guarujá, Brazil (2018).



Source: Collection of authors' data.

Table 1. Coordinates of the collection sites (P) in the Tejereba river and their characteristics.

Sites	**Coordinates**	**Charactheristics**
P1	23°58'55.04"S46°14'48.07"W	Degraded original vegetation; presence of clandestine settlements; dark colored water and with presence of foam; strong odor characteristic of domestic sewage.

P2	23º59'01.35"S46º14'51.29"W	Degraded original vegetation; presence of clandestine settlements; dark colored water and with presence of foam; strong odor characteristic of domestic sewage.
P3	23º59'01.49"S46º14'54.65"W	Degraded original vegetation; dark colored water and with presence of foam; strong odor characteristic of domestic sewage; no urban occupation.
P4	23º59'07.67"S46º14'57.80"W	Degraded original vegetation; dark colored water and with presence of foam; strong odor characteristic of domestic sewage; Presence of urban occupation (buildings and houses).
P5	23º59'11.10"S46º14'55.48"W	Degraded original vegetation; light colored water; strong odor characteristic of domestic sewage.
P6	23º59'14.67"S46º14'53.81"W	Degraded original vegetation; light colored water; strong odor characteristic of domestic sewage.
P7	23º59'22.62"S46º14'51.17"W	Original vegetation preserved; light colored water; strong odor characteristic of domestic sewage.
P8	23º59'28.29"S46º14'50.78"W	Original vegetation preserved; light colored water; strong odor characteristic of domestic sewage.
P9	23º59'31.16"S46º14'51.29"W	Site located at Enseada beach; dark colored water and with presence of foam; strong odor characteristic of domestic sewage.

Source: Collection of authors' data.

The water samples were collected in triplicate using a collecting container tied in a string to reach greater depths. After collection, the samples were stored in amber flasks and transported in a styrofoam box with ice to the Ecotoxicology Laboratory of the Universidade Santa Cecilia (UNISANTA, Santos-SP), where they were analyzed.

2.3 Physicochemical and microbiological characterization

Salinity analyses (ppm) were performed using a portable refractometer (Shibuya145), pH was measured using a pH meter (MicronalB474) and turbidity calculated using a turbidimeter (PolicontrolAP2000). Nitrite and nitrate were determined by the N-(1-naphthyl) ethylenediamine * (NTD) method, adapted from *Standard Methods* 21a ed4500b, 4-118(2005). Determinations were performed by measurements in a spectrophotometer (CELME-225-D) at 535 nm (Roveri, 2013).

Ammonia concentration was determined as ammoniacal nitrogen by the 4500-D volumetric methodology, with preliminary, distillation as described in the Standard Methods for the Examination of Water and Wastewater (APHA, 1999). First, 500 mL of the sample were buffered to pH 9.5 with 25 mL of borate buffer. After that, the sample was distilled and ammoniacal nitrogen was collected in 50 mL of an absorbent solution of boric acid. This distillate was then titrated using a colored indicator.

Phosphate determination was performed using the molybdenum blue method. The determinations were carried out by measuring the absorbance in the spectrophotometer (CELM E-225-D) at 650 nm. The results of the phosphate contents of the samples were calculated using a phosphate standard curve (Alfakit), with concentrations ranging from 0.3125 to 10 mg L^{-1}.

For the determination of *Escherichia coli* and other coliforms in the samples, we adopted the membrane filtration technique (modified from CETESB 2004 and APHA 2012). For this, the collected samples were homogenized manually and diluted 100000x. After dilution, the samples were filtered (10 mL) through a sterile membrane (0.45 μm, Millipore) and placed in Petri dishes containing Biochrome Coliform Agar (Biolog) culture medium. The culture medium used in the assay is a chromogenic medium that allows rapid identification and simultaneous counting of *E. coli* and other coliforms, where differentiation is performed from colony staining (Manafi, 1996; APHA, 2012). After filtration, plates containing the culture medium and the membrane were placed in trays in an inverted position and incubated at 35 ± 0.5 ° C for 22-24 hours.

After the incubation time, the total number of coliforms and *E. coli* colonies was counted. Results were expressed as Colony Forming Units (CFU)/100mL according to the equation (1): CFU/100mL = NTC x DE x 100/VFA; in which: NTC-total number of colonies; ED- employed dilution; VFA-volume of filtered sample (mL).

2.4 Toxicological characterization

For the 3 sample collections, toxicological tests were performed using *Daphnia magna* as a model organism. Toxicity tests are standardized by ABNT NBR and CETESB, and they consist of exposing young individuals of *Daphnia magna* to various toxic agent concentrations under the conditions prescribed in the standard (NBR12713). In the present study, four neonatal *D. magma* individuals were used for each collection point. The tests were performed with fresh water without previous dilutions. The batch of organisms does not exhibit toxicity if the immobility and/or mortality rate does not exceed 10% over a 48-hour exposure period.

2.5 Statistical analysis

Results were expressed as mean ± standard deviation for each point analyzed per collection ($N = 3$). Statistical difference ($p > 0.05$) between the mean values of the physicochemical variables of water by collection period ($N = 9$) was determined by analysis of variance (ANOVA), followed by Tukey's *a posteriori* test and, in case of errors in normality, the Kruskal-Wallis test. Statistical analyses were performed using SigmaStat software and graphs were developed using SigmaPlot software. A principal component analysis was performed to verify relations between the physicochemical and microbiological variables of the water and the floating population and precipitation index of the collection months. For this, the program PAST version 2.17 was used.

3. Results

3.1 Hydrogen ion concentration (pH)

In the present study, pH values ranged from 6.90 to 7.2. The CONAMA Resolution n° 375/2005 states that pH should vary between 6.0 and 9.0 in waterbodies labeled as Class 2 freshwater; thus, all samples were within the limits recommended by this norm (Figure 3A). No significant difference ($p<0.05$) was observed between collection period (Figure 3A).

3.2 Turbidity

The turbidity ranged from 8.32 to 19.36 UNT, displaying values within the limits established by the CONAMA resolution n° 375/2005, which determines that it should be less than or equal to 40 UNT (Figure 3B). No significant difference ($p<0.05$) was observed between collection period (Figure 3B).

3.3 Ammoniacal nitrogen

Ammoniacal nitrogen concentration ranged from 0.36 to 1.93, with the highest concentrations found at points 01 and 09 in the collections performed in May (Figure 3C). Ammoniacal nitrogen concentration did not exceed 2.0 mg L^{-1}, the limit allowed by CONAMA Resolution n° 357/2005. When the average ammoniacal nitrogen concentration was evaluated per collection period, a significant increase ($p<0.05$) was observed in the third collection compared to the first and the second ones, as well as a significant increase ($p<0.05$) in the first collection compared to the second one (Figure 3C).

3.4 Nitrite and nitrate

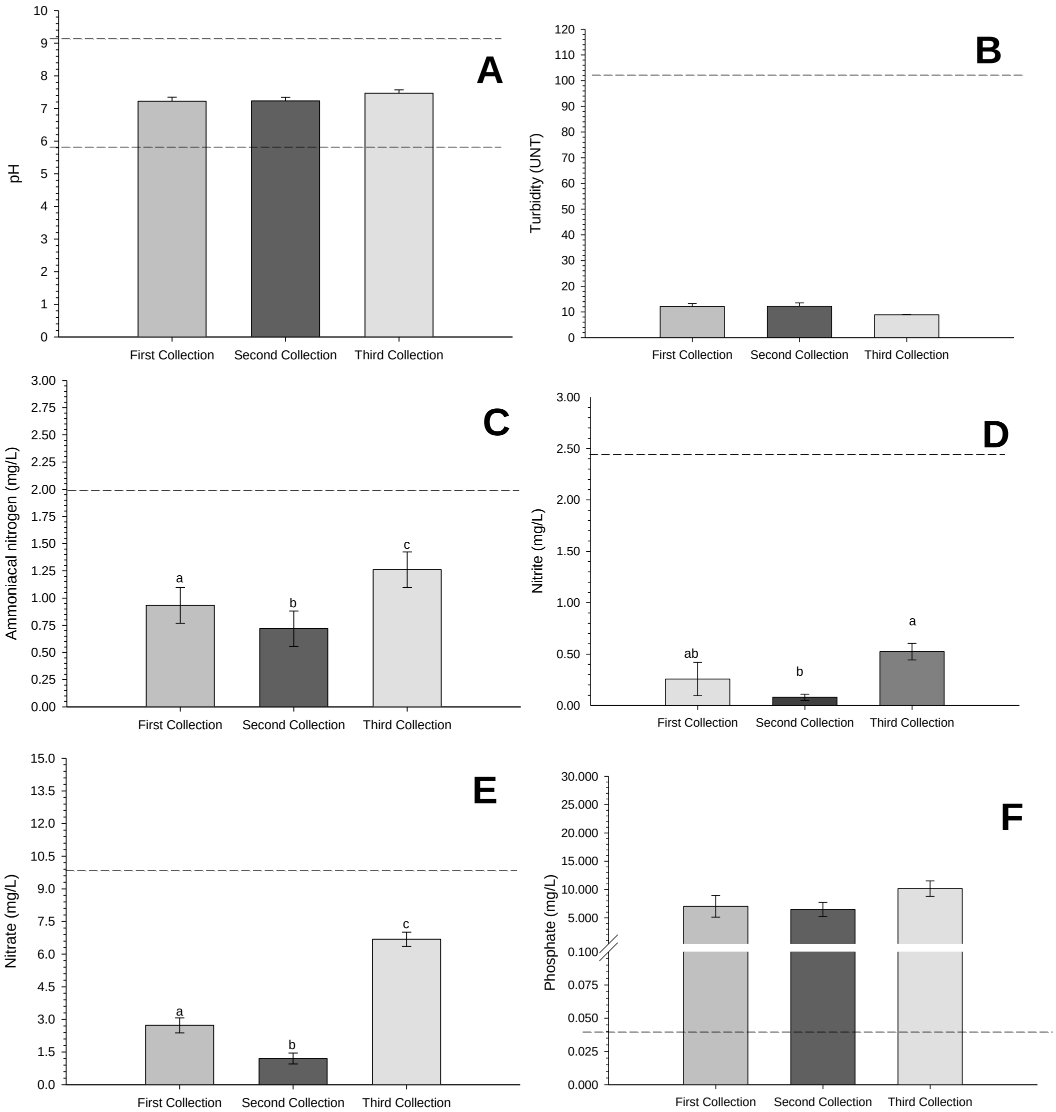
In this study, it was found that nitrite concentration ranged from 0.008 to 1.6 mg L^{-1}, being within the range established by CONAMA 357/2005 resolution of 2.5 mg L^{-1} (Figure 3D). When the mean values were evaluated per collection, it was found that in the second collection, the average value of nitrite was higher ($p<0.05$) compared to the third collection (Figure 3D).

Nitrate concentration ranged from 0.09 to 8.35 mg L^{-1}, a value below the limit of 10 mg L^{-1} established by CONAMA Resolution 357/2005 (Figure 3E). By evaluating the average values per collection, it was verified that in the first collection, the average concentrations of nitrate were higher ($p<0.05$) in relation to the second and third collections; however, these values were lower in the second collection when compared to the first and third collections (Figure 3E).

3.5 Phosphate

The results of dissolved phosphate show values above the limits established by CONAMA Resolution No. 357/2005 (0.05 mg L^{-1}) in the three collections performed. It was also found a concentration about 10 times the limit in points 05 and 06 in January (Figure 3F). When the average phosphate concentration was evaluated per collection period, no significant changes ($p<0.05$) were observed between the samples (Figure 3F).

Figure 3. Mean ± SEM of water (A) pH; (B) Turbidity; (C) Ammoniacal nitrogen; (D) Nitrite; (E) Nitrate; and (F) Phosphate in the Tejereba River (Guarujá, Brazil) in the collection sites per month. The dashed line indicates limit values established by CONAMA's Resolution 357/2005 (water class 2). Different letters indicate statistical differences between collections.

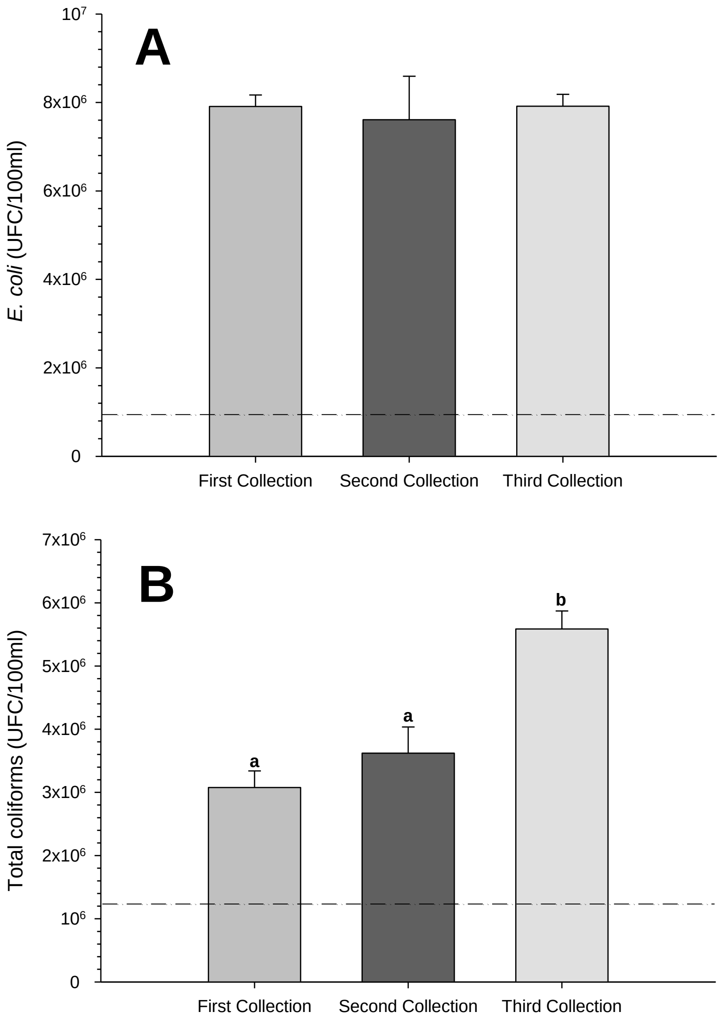


Source: Collection of authors' data.

3.6 Microbiological characterization

In the present study, total coliforms and *E. coli* were detected in all collected samples, as shown in Figure 4. The samples collected presented *E. coli* and total coliforms values above the limits established by CONAMA Resolution n°. 375/2005 ($0.2x10^4$ CFU/100mL) (Figure 4A and B). Significant increase ($p<0.05$) was observed in the third collection when compared to the first and second collections only for total coliforms (Figure 4B).

Figure 4. Mean ± SEM of E. coli (A) and total coliforms (B) in the Tejereba River (Guarujá, Brazil) in the first (January), second (February), and third (may) water collections in Guarujá, Brazil (2018). The dashed line indicates limit values established by CONAMA's Resolution 357/2005 (water class 2). Different letters indicate statistical differences between collections.



Source: Collection of authors' data.

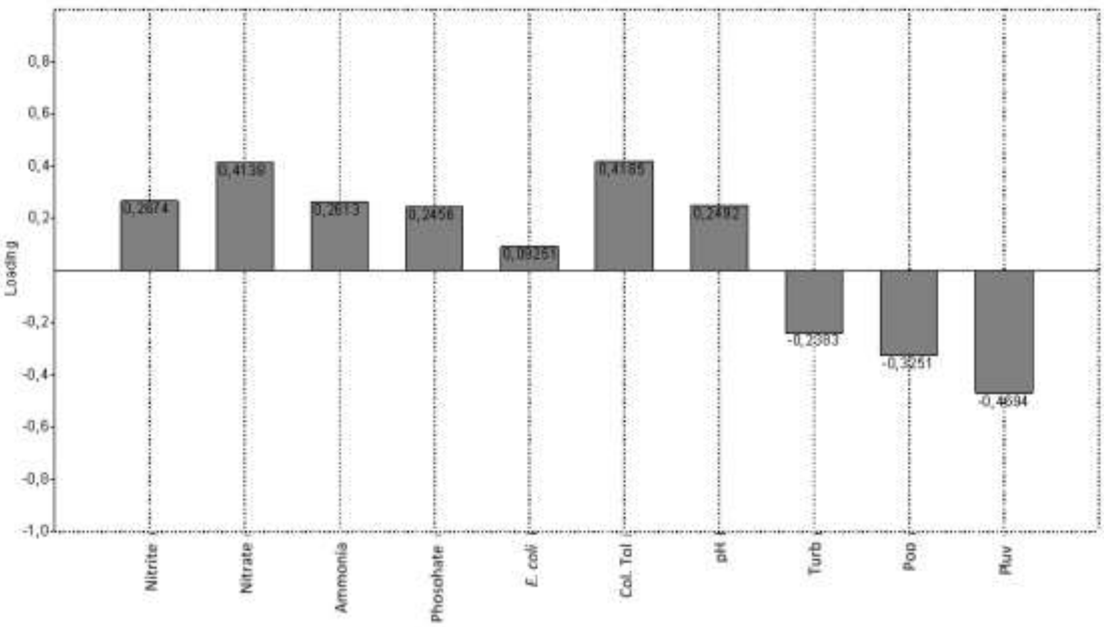
3.7 Toxicological characterization

The waters collected in January, March, and May of 2018 from the Tejereba River, located in Guarujá, Brazil, showed no toxicity, since the immobility and/or mortality index was null (0%) for *Daphina magna*.

3.8 Integrated data analysis

In order to give an integrated overview of the data, a principal component analysis (PCA) was performed using physicochemical parameters, precipitation index and fluctuating population in the investigated months (January, March and May). The analysis showed that the first two axes of the PCA explained, concomitantly, about 50% of the data variability (axis 1, 37.1% and axis 2, 15.44%). The points in January showed higher precipitation, floating population percentage and turbidity, while showed low concentration of the other variables (nitrate, nitrite, ammoniacal nitrogen, phosphate, *E. coli*, total coliforms, and pH). The results were the opposite for the other variables: the points in March and May showed high concentrations of nitrate, nitrite, ammoniacal nitrogen, phosphate, *E. coli*, total coliforms, and pH, and low concentrations in the month of January (Figures 5 and 6).

Figure 5. Load values for each studied variable after PCA analysis.



Source: Collection of authors' data.

Research, Society and Development, v. 9, n. 11, e3699119280, 2020
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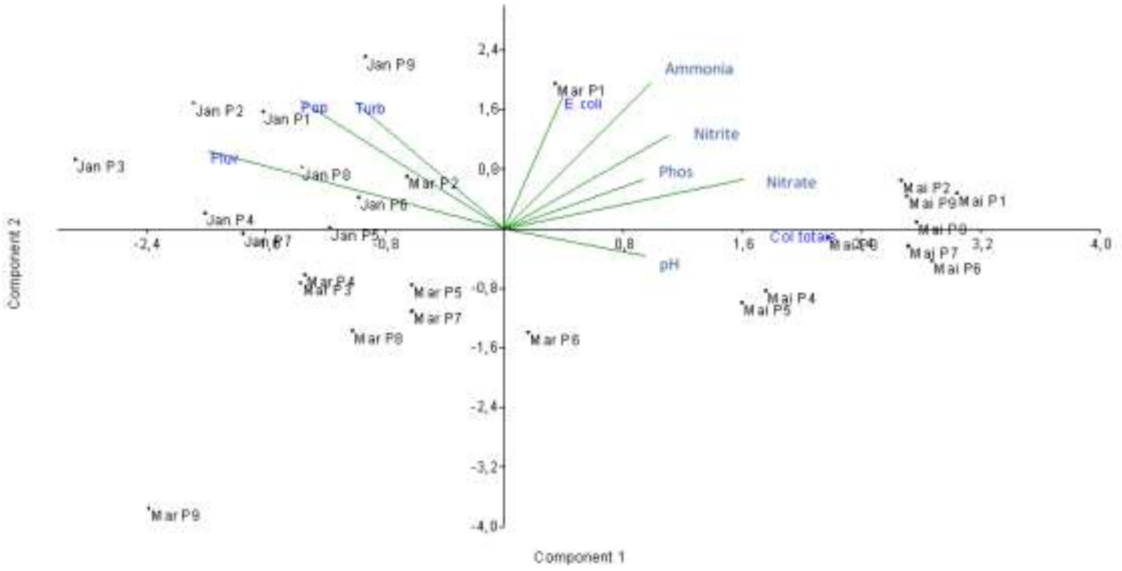
Figure 6. PCA graph, showing the components 1 (37.1%) and 2 (15.4%), the distributions of the collection sites, and the variables during the first (January), second (February), and third (may) water collections in Guarujá, Brazil (2018).



Source: Collection of authors' data.

4. Discussion

The present study aimed to evaluate the water quality of the Tejereba River (Guarujá, Brazil), which flows into a coastal beach, and correlate to the high (January) and low (March and May) touristic season of 2018. The concentration of ammonia, nitrite, nitrate, and total coliforms in water samples collected at different points of the river were significantly higher in May (low tourism, lower precipitation) when compared to January and March (high/medium tourism, higher precipitation). The integrated data analysis (PCA) showed a positive correlation between the physicochemical parameters and May, in which they were negatively correlated with precipitation and the percentage of tourists in the city during this month. Despite the deterioration of water quality in May, none of the monitored months showed toxicity when measured by the standardized test (NBR 12713 and CETESB) with *Daphnia magna*. The present data indicated that the water quality (physicochemical and microbiological parameters) of the Tejereba River (Guarujá, Brazil) is more related to precipitation than to the presence of tourists in the investigated months.

The Tejereba River is neither considered a recreation place nor used for urban supply; however, it flows into a beach much appreciated by tourists. Consequently, the water quality of rivers flowing into such tourist sites should be monitored. The physicochemical and microbiological parameters quantify how much a waterbody can be modified due to the direct or indirect addition of substances, causing damage to its multiple uses (D'Águila, 1996; Sperling, 2005). Maintenance of water quality and integrity of waterbodies are worldwide problems, and several works have been performed to evaluate the quality of these environments (Cassanego, 2017; Federigi et al. 2016). In the present study, considering the evaluated physicochemical and microbiological parameters, only phosphate and total and fecal coliforms presented results above the limit established by the Brazilian resolution CONAMA n° 357/2015, as well as its updates n° 410/2009 and n° 430/2011 for class 2 waters (freshwater) for all samples pH, turbidity, nitrite, nitrate, and ammoniacal nitrogen were within the limits established by this resolution.

Changes in pH may be related to natural (rock dissolution, absorption of atmospheric gases, oxidation of organic matter, and photosynthesis) and anthropogenic factors, such as the discharge of domestic sewage (Sperling, 2005). Tejereba River's pH results did not indicate risks to this ecosystem; pH was near neutrality throughout the study. When very acidic or basic pH values are detected, there may be an imbalance in the food chain and, therefore, an inhibition of benthic and planktonic activity. The pH in the range found in this study (between 6.5 and 8.5) can be considered normal (without impact) for a waterbody (Hermes & Silva, 2004). However, the natural limnological characteristics of each region, such as the presence of naturally acidic waters (i.e. freshwaters from Amazon region), have to be taken into account when studying the pH ranges of natural waterbodies (Arcos, Silva & cunha, 2020).Thus, the fact that the samples showed a pH close to neutrality does not necessarily mean that there is an absence of polluting substances discharged into the Tejereba River. These results are similar to other studies performed in the same river in 2013, whose values ranged from 6.80 to 7.33 (Roveri, 2013). Similarly, McKenzie & Young (2013), when monitoring urban water flow in two distinct areas (urban area and highways), detected pH results between 7.0 to 8.2, similar results to those found in the Tejereba River.

Although the stream is affected by the interference of a clandestine domestic sewage, stormwater drainage, and commercial activities (including the graveyard between points 02 and 03), turbidity results did not present much variation between points and they were below the limit established by the Brazilian resolution CONAMA 357/2015. Even during the rainy season (first and second periods of sampling of this study), when higher turbidity values would be expected due to the greater transport of particles by surface flow to waterbodies (Dussart et al. 2003; Silva et al. 2003; Valdes et al. 2005), no major alterations of this variable were observed in the studied river.

Regarding the nitrogen series in all samplings, the predominance of nitrate over ammoniacal nitrogen was observed, suggesting a polluting event from ancient or distant sources (Cassanego, 2017; Zotou et al. 2018). This condition may be justified by the fact that the water flow in this river is slow and it has already received domestic sewage for many years. Therefore, the results suggest old pollution in this river. The total ammoniacal nitrogen, nitrite, and nitrate concentrations in the Tejereba River was different from maximum concentrations of total nitrogen (> 9.0 mg L^{-1}) detected in studies carried out in the Maratuã and Crumaú rivers that flow into an estuarine area on the coast of São Paulo. Studies conducted by Han et al. (2017) have shown that the diffuse load of nitrate into waterbodies is responsible for eutrophication, fish mortality and loss of aquatic biodiversity (Han et al. 2017).

The high concentration of phosphates is a concern in this study, since, as well as the nitrogen-derived compounds, phosphates in the marine environment can contribute to the eutrophication of the ecosystem (CETESB, 2007) and cause the proliferation of toxic algae, with direct effects on biocenosis (Zotou et al. 2018). In addition, eutrophication may hinder recreational activities on Enseada beach. In extreme cases, some toxins generated by the large phosphate intake may contribute to neurological or respiratory problems in humans (Kirkpatrick et al. 2004).

The concentration of total and fecal coliforms was above the established limit ($0.2x10^4$ CFU/100mL). The presence of total coliforms can be associated with fecal contamination and, in the present study, it exceeded by 4000x the limit in the three collections performed. The concentration of fecal coliforms surpassed the limit established by the legislation by 1500x, 1750x and 3000x in the months of January, March, and May, respectively. Although the above-mentioned parameters exceeded the limits preconized by Brazilian legislation in the whole investigated time interval, there was an increase in the concentration of fecal coliforms in May. Unexpectedly, this month had a lower percentage of tourists compared to other months (about 5% less tourists) and, at the same time, lower precipitation. Da Silva Sousa et al. (2016) verified the water quality of Rio Grajaú, in the municipality of Grajaú (MA, Brazil) were no differences in the total coliforms concentrations where found. It is possible to speculate that, in the present study, the decrease in precipitation caused a decrease in water dilution, leading to a higher concentration of fecal coliforms in the environment, even when this period is related to a lower percentage of tourists.

On the other hand, the presence of total coliforms in high concentrations in all the investigated months, regardless of higher or lower precipitation/floating population, may be related to the continuous discharge of domestic effluents in this river. The presence of these bacteria in the Tejereba River indicate a potential health risk, as these waters flow directly into a beach much appreciated by tourists. Studies in Europe have shown that these pathogens, when carried to the beaches via rain drainage channels during rain episodes, are responsible for the systematic loss of beach bathing (Federigi et al. 2016). They are also a potential public health risk, since exposure to them in these recreational waters is associated with an increased risk of gastrointestinal diseases; respiratory, eye, ear, and skin infections; besides meningitis and hepatitis (Schets et al. 2011); moreover, during the summer, when tourists and sewage discharges increase, gastroenteritis events are aggravated (Sunderland et al. 2007). The fact that *E. Coli* was detected in high concentrations in all sampling periods indicates an anthropic interference from the Enseada's clandestine sewage, since the bacteria is an important marker of domestic sewage, and it is present in human feces between 96 and 99% (Vitorino, 2018). These results are very similar to the ones presented by another study performed in these same waters in 2013, which also detected high concentrations of *E. coli* in these drainage channels (Roveri, 2013); demonstrating that after 5 years, the sanitation conditions of Cove Beach showed no improvement. The Brazilian environmental monitoring agency (CETESB) monitors 8 of the 26 beaches of the municipality on a weekly basis (on Sundays) by using *Enterococcus* as the microbiological indicator. Several rivers along Guarujá (among them, the Tejereba River) are sampled twice a year and are analyzed by using *E. coli* as an indicator. The results of *E. coli*, monitored by CETESB, also corroborate this study, presenting high concentration of this bacteria in the river (CETESB, 2017).

The multivariate analysis conducted in the present study shed light on the most significant relationships between floating population and pluviosity variables, and the water physical-chemical and microbiological characteristics. The PCA analysis highlighted a seasonal pattern related with the rainy periods, where higher precipitation decreased the levels of the nitrate; nitrite; ammoniacal nitrogen; phosphate; *E. coli*; total coliforms; and pH, even with high floating population percentage found in this collection periods. This information improved the discriminatory power of the adopted strategy to characterize the studied sites and provided a comprehensive indication of ecosystem health of the Tejereba River on the studied months.

5. Conclusion

When considering the limits established by CONAMA's Resolution 357/2015, the Tejeraba River presented contaminated conditions especially by the high levels of phosphate and total and fecal coliforms. A negative relationship between precipitation, but not with the floating population, and elevated concentrations total coliforms and nitrate was evidenced by the PCA analysis. These results provided a comprehensive indication of ecosystem health of the Tejereba River on the studied months.

Acknowledgements

The authors would like to thank the Universidade Santa Cecília and PPG-ECOMAR.

Data Availability Statement

The authors declare that the data will be available to be shared if requested.

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