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Influence of land use and occupation on the water quality of the Biritiba Mirim Reservoir (Upper Tietê Producer System/SP)

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ABSTRACT
The metropolitan region of São Paulo has around 21 million inhabitants, and eight water producer systems are used to supply water to this population, including the Upper Tietê Producer System, which is responsible for 15% of the supply and composed of five reservoirs. Agricultural activities are the economic base of the Biritiba Mirim reservoir and land use to this end is sometimes extended to its surroundings, which might compromise water quality due to the excessive use of fertilizers, and pesticides, among others. This study aimed to assess water quality from the Biritiba Mirim reservoir, in the city of Biritiba Mirim/SP, and its relationship with land use and occupation. We performed four quarterly collections (August and November 2019 and February and May 2020) in ten sampling stations spatially distributed in the reservoir (close to the area with the presence of riparian forest and agricultural areas). We measured the physical, chemical, and microbiological variables of water, in addition to the Water Quality Index and the Trophic State Index. The analyses revealed that all variables are within the limits established by the CONAMA 357/2005 legislation, except for phosphorus total, whose values, in two different areas, reached concentrations above the legal limit. We highlight the highest values were recorded in areas surrounding crops, as well as the higher concentration of total phosphorus in such areas, which might be linked to phosphate fertilization, carried out at each cultivation, whose residues end up loaded inside the water body.

KEYWORDS: Trophic State Index. Water supply reservoir. Metropolitan region of São Paulo.

1 INTRODUCTION

Brazil has privileged water resources, covering roughly 12% of the world’s availability. However, there are major regional differences when analyzing its distribution throughout the surface territory. Such a scenario is clearer in the North region, which represents 44% of the territory extension and covers around 70% of water resources but shelters only 4.5% of the Brazilian population. In turn, the Northeast and Southeast of Brazil, with 13% and 15% of the population, have 0.5% and 2% of water availability, respectively (GALLI; ABE, 2010).

The Metropolitan Region of São Paulo – MRSP is the most populated urban conurbation in Latin America, with around 22,048,504 inhabitants (IBGE, 2021), hence with a huge water demand. Its population is almost entirely inserted in the Upper Tietê River Basin (IBGE, 2021). According to Whately and Diniz (2009), the MRSP has seven times less water per inhabitant than the critical level considered by the United Nations Organization (UNO). The MRSP population is distributed throughout an area of 8,051 km^2, around 0.1% of the whole Brazilian territory, but contains an urban expansion of roughly 2,209 km^2 (IBGE, 2021). The main challenge then arises: how to supply good quality and enough water to 10% of the Brazilian population concentrated in less than 0.1% of the national territory?

Meeting the current supply demand for the MRSP population requires eight water producer systems, including the Upper Tietê System, whose regular functioning provides 15 m^3/s of water to the MRSP, contributing to supplying roughly 4.5 million people (SIRVINKAS, 2020). The Upper Tietê Producer System is composed of five reservoirs, including the Biritiba Mirim, in the cities of Biritiba Mirim and Mogi das Cruzes, whose economy is partially agriculture-based. In the surroundings of the Biritiba Mirim reservoir, the riparian forest has been removed and land use ends up extending to its surroundings, thus favoring the loading of the derived material to the water body. Such a scenario might compromise the natural geochemical features of the area, hence water quality (SARTORI, 2015; TRINDADE, 2016), thus impacting several contexts, such as the ecological balance (birds, fish, and plants), including

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human consumption.

Thereby, reservoirs, as part of river basins, suffer the effects of anthropogenic actions, which can change water bodies significantly. Thus, reservoirs close to areas with intensive agricultural activity might have higher concentrations of sediments, nutrients, and metallic minerals due to the presence of pesticides (MALLASEN et al., 2012), as observed by Trindade (2016) and Sartori (2015) when recording the change in water quality in the Biritiba Mirim reservoir, especially due to agricultural activities.

These activities involve the inadequate disposal of residues, pesticides, and application of phosphate fertilizers, which, in addition to causing soil contamination, contribute to the eutrophication of water bodies, one of the main issues responsible for lower water quality for human supply (TRINDADE, 2016).

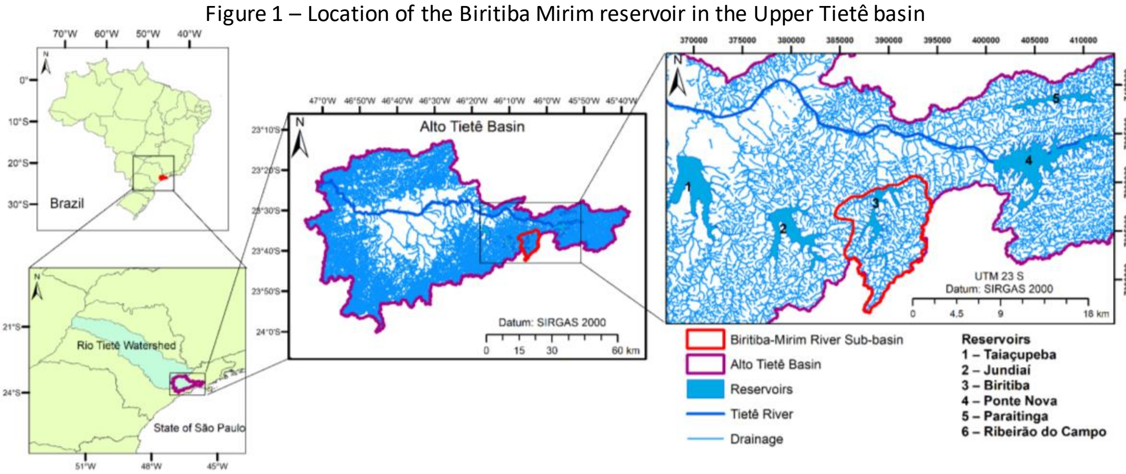
Therefore, we hypothesize that land use and occupation in the surroundings of the Biritiba Mirim reservoir influence the limnological feature of water, with higher concentrations of total phosphorus, total nitrogen, and chlorophyll *a*, leading to a greater trophic degree in areas close to the absence of riparian forests. Thus, this study aimed to assess the spatial (horizontal) and temporal (seasonal) limnological features of the Biritiba Mirim reservoir and compare them regarding the use and occupation of the reservoir, including its basin.

2 MATERIAL AND METHODS

2.1 Study area

The Biritiba Mirim reservoir is in the Eastern region of the São Paulo state and is part of the Water Resources Management Unit (UGRHI – abbreviation in Portuguese) 06 of the Upper Tietê (Figure 1). The regional climate is subtropical, and the mean annual temperature is 20º C, where July is the coldest month (mean of 15º C) and February is the hottest month (mean of 23º C). The mean annual rainfall is 1300 mm.

Figure 1 – Location of the Biritiba Mirim reservoir in the Upper Tietê basin



Source: Based on data by the authors.

The reservoir is part of the Upper Tietê Producer System (SPAT), responsible for 15% of the water supply in the eastern part of the MRSP. This system works in an interconnected

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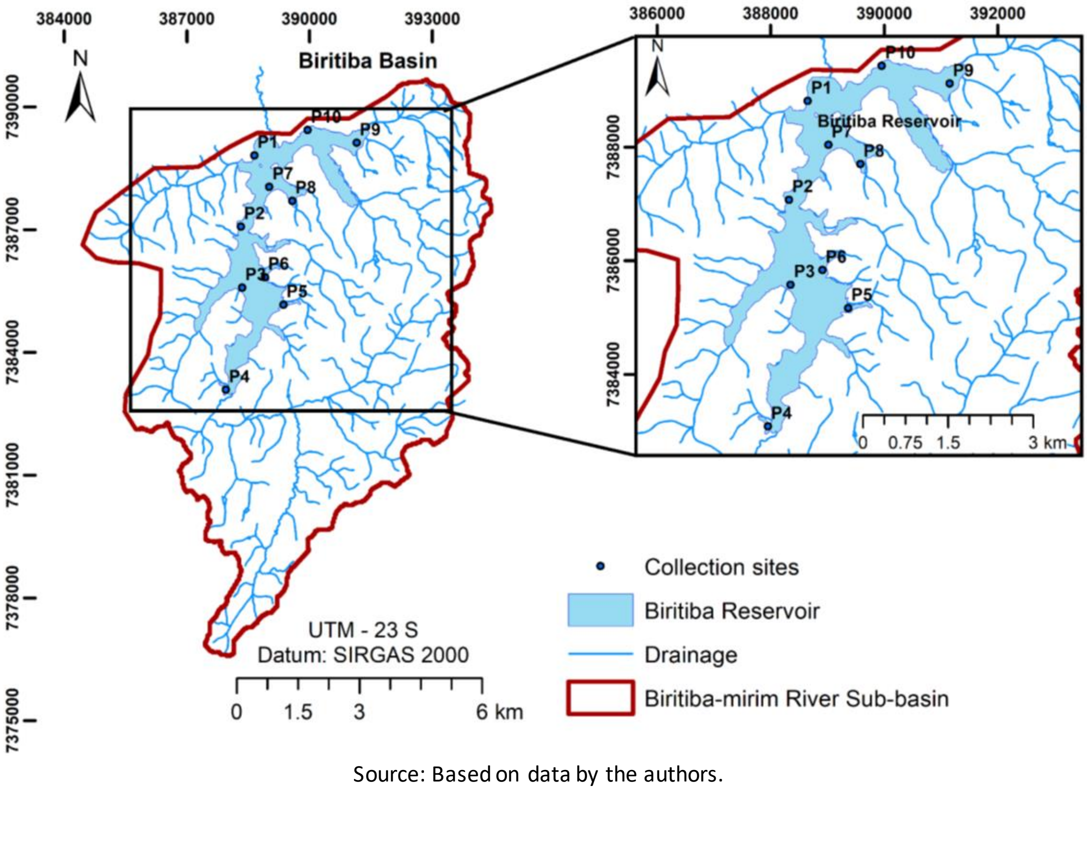
manner (Figure 1) and is composed of the Paraitinga and Ponte Nova reservoirs, in the city of Salesópolis; the Biritiba Mirim reservoir, the same name as the city; the Jundiaí reservoir, in Mogi das Cruzes; and the Taiaçupeba reservoir, in Suzano, which is responsible for water collection, treatment, and distribution, managed by the Companhia de Saneamento Básico do Estado de São Paulo – SABESP. The Biritiba Mirim reservoir covers a drainage area of roughly 75 km² formed by the damming of the waters of the Biritiba Mirim River, the left bank tributary of the Tietê River (TRINDADE, 2016).

2.2 Experimental design

We collected the water samples quarterly throughout a seasonal cycle (between August and November 2019 and between February and November 2020) in ten different sampling stations in the Biritiba Mirim reservoir. The sampling stations were defined based on the criterion of land use on the margins of the reservoir, as recommended by Trindade (2016), with five stations close to the area with the presence of riparian forest and five stations close to the areas with agricultural activity (Figures 2 and 3). The sampling stations were marked using the Global Positioning Satellite System (GPSMAP 76CS/Garmin) (Table 1).

Figure 2 – Location of the Biritiba Mirim reservoir, highlighting the location of the collection stations



Source: Based on data by the authors.

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Figure 3 – Images of the sampling stations in the Biritiba Mirim reservoir

Source: Based on data by the authors.

Table 1 – Geographical coordinates and surrounding features of the water sampling stations of the Biritiba Mirim reservoir, SP

Collection sites	Coordinates	Features of the surroundings
P 1	- 23.6074; - 46.0914	Presence of riparian forest
P 2	- 23.6231; - 46.0948	Presence of riparian forest
P 3	- 23.6366; - 46.0946	Presence of agriculture
P 4	- 23.6591; - 46.0987	Presence of agriculture
P 5	- 23.6404; - 46.0847	Presence of riparian forest
P 6	- 23.6343; - 46.0891	Presence of riparian forest
P 7	- 23.6144; - 46.0879	Presence of agriculture
P 8	- 23.6175; - 46.0824	Presence of agriculture
P 9	- 23.6048; - 46.0669	Presence of agriculture
P 10	- 23.6019; - 46.0786	Presence of riparian forest

Source: Based on data by the authors.

2.3 Analysis of limnological variables

We collected the water samples on the subsurface of the water column, which were transported and stored in proper flasks, according to the procedures of the Sample Collection and Preservation Guide, provided by the National Water Agency (CETESB, 2011). The following *in situ* features were analyzed: water temperature, dissolved oxygen, electrical conductivity, pH, and turbidity (Horiba Model U22). The water samples were sent to the Water Analysis Laboratory of the Fisheries Institute of the State of São Paulo and the Environmental Sciences Laboratory of the UNG University. In the laboratory, biochemical oxygen demand, total nitrogen, ammonium ion, nitrite, nitrate, total phosphorus, orthophosphate, total solids, alkalinity, Escherichia coli, and chlorophyll *a* were analyzed. The following methodologies were used: manometric method (VELP CIENTÍFICA, 2016) for biochemical demand; Valderrama (1981) for

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total nitrogen and total phosphorus; Mackereth et al. (1978) for ammonium ion, nitrite, and nitrate; Strickland and Parson (1960) for orthophosphate, and APHA (2012) for alkalinity and *Escherichia coli*.

Glass microfiber filters (AP 20) with a diameter of 47 mm were used for chlorophyll *a* analysis. After filtering, the filters were wrapped in aluminum foil and stored in a freezer until analysis in the laboratory. Extraction using ethanol as a solvent and analysis followed the technique proposed by Wetzel and Likens (2000).

The results of the limnological analyses allowed us to calculate the Trophic State Index (TSI), according to Lamparelli (2004), and the Water Quality Index (WQI), according to the CETESB (2020).

2.3 Mapping of Land Use and Occupation

Free software programs and Sentinel-2 satellite images were used to develop the maps of land use in the Biritiba reservoir.

Sentinel-2A and 2B form a multi-spectral Sentinel-2 imaging mission of the GMES (Global Monitoring for Environment and Security) Program, jointly managed by the European Community and the European Space Agency (ESA) for Earth observation, collecting data on vegetation, soils, and humidity, rivers and coastal areas, as well as high-resolution (10 m) data for atmospheric correction (absorption and distortion), with a high revisit capacity (5 days) to ensure data continuity provided by SPOT 5 and Landsat 7 (ENGESAT, 2017), whose images are freely available on the USGS – Earth Explorer website.

The Biritiba Mirim basin reservoir (Figure 2) is the area defined for the map of land use and occupation. The classes were defined based on water pollution potential and the concentration of chlorophyll *a* close to these classes.

The methodology for the characterization and mapping of land use categories was based on the following steps:

- Creating a base map containing the study area limits, drainage, coordinates, and collection sites.

- Creating a key of spectral classes.

- Choosing the object-driven image (Geobia) type of classification on the SAGA GIS free software. The advanced step will encompass a more robust software analysis, including the programs Geodma 0.2.2a, QGIS, GeoDa, and SAGAGIS. These analyses aim to address the highlights of these programs and provide more elements for a satisfactory object-driven classification.

Thus, the maps of land use and occupation and updated photographic documentation of the region allowed the application of the process of Multicriteria Analysis (or Map Algebra). Such a process is fundamental to cross-reference the results and reach a final, accurate, and thorough diagnosis of the land use and occupation scenario and its implications for the Biritiba Mirim reservoir. All phases described were carried out at the Geoprocessing Laboratory of the UNG University, which has extensive experience in such procedures.

3 RESULTS AND DISCUSSION

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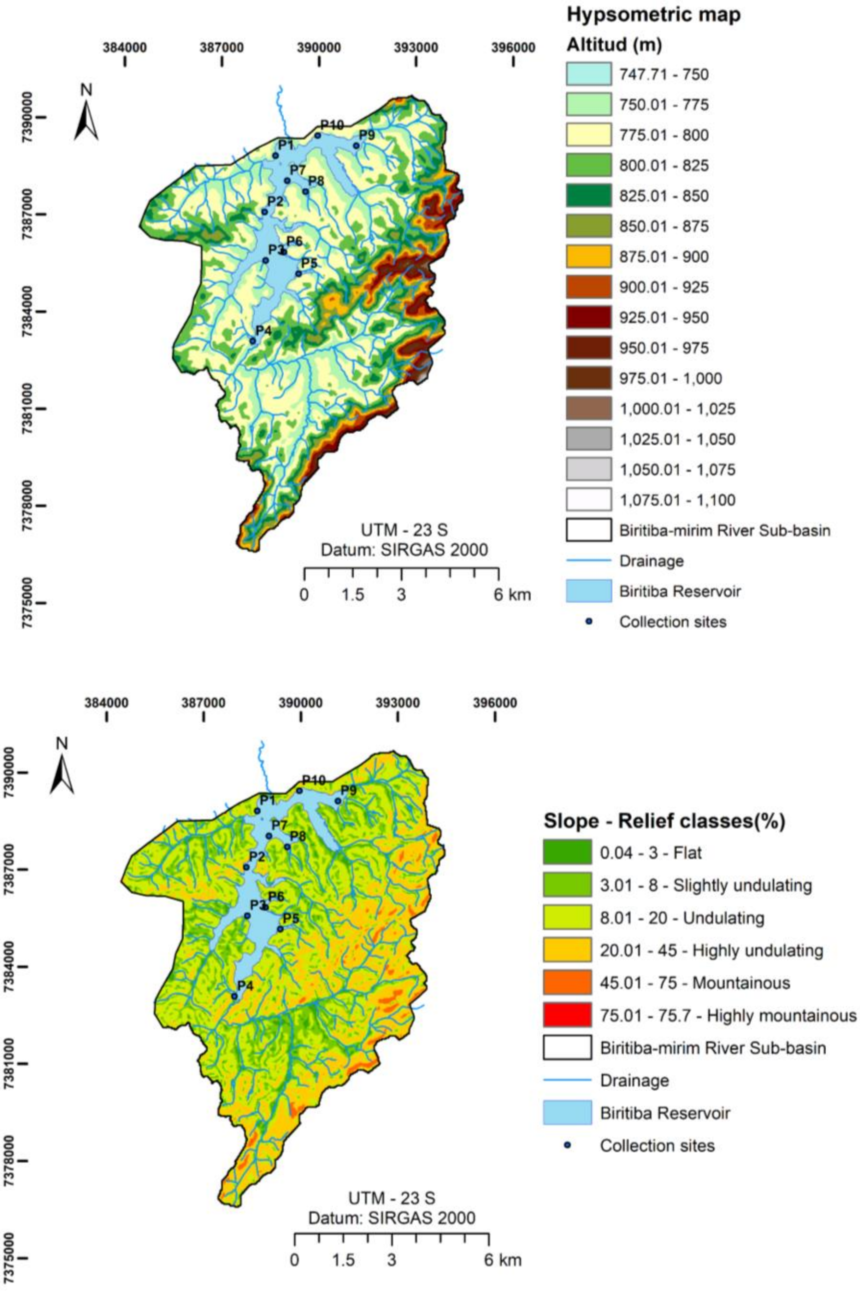
3.1 Characterization of the water basin of the Biritiba Mirim Reservoir

The Biritiba Mirim basin reservoir has an approximate drainage area of 75 km² formed by the damming of the waters of the Biritiba Mirim River. The hypsometric map (Figure 4A) represents the altitude variation of an area concerning sea level, where the altitude is zero, using a color scale. The eastern edge of the study area has the highest altitudes. The central part and the western edge have altitudes of around 800 to 850 meters. As for the slope (Figure 4B), there is a predominance of slightly undulating relief. And on the eastern edge, there is mountainous and strongly mountainous relief.

Figure 4 - Hypsometric and slope maps of the Biritiba Mirim Reservoir



Source: Based on data by the authors.

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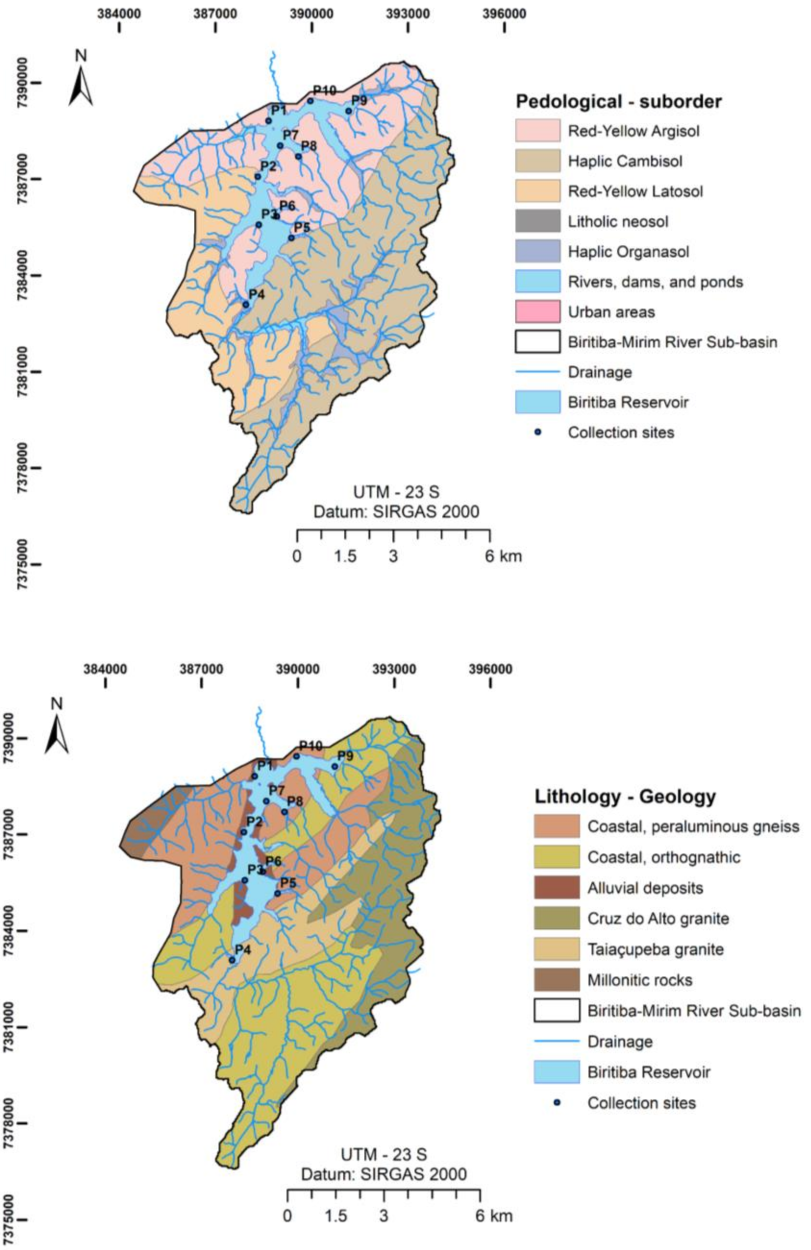
Pedological maps are important documents and databases for land planning and management. They are basic sources for research and studies in agriculture, geotechnics, geography, biology, geology, and environmental sciences, among others. An analysis of the pedological characteristics of the studied area reveals the presence of Red-Yellow Argisols to the north, Haplic Cambisol in the central east, and Red-Yellow Latosols on the western edge (Figure 5A). The lithological map shows a wide variety of rock formations in the study area with the presence of Cruz do Alto Granite on the eastern edge, in the northern and western parts, and the presence of coastal, orthognathic units in the south (Figure 5B).

Figure 5 – Pedological and lithological maps of the Biritiba Mirim Reservoir



Source: Based on data by the authors.

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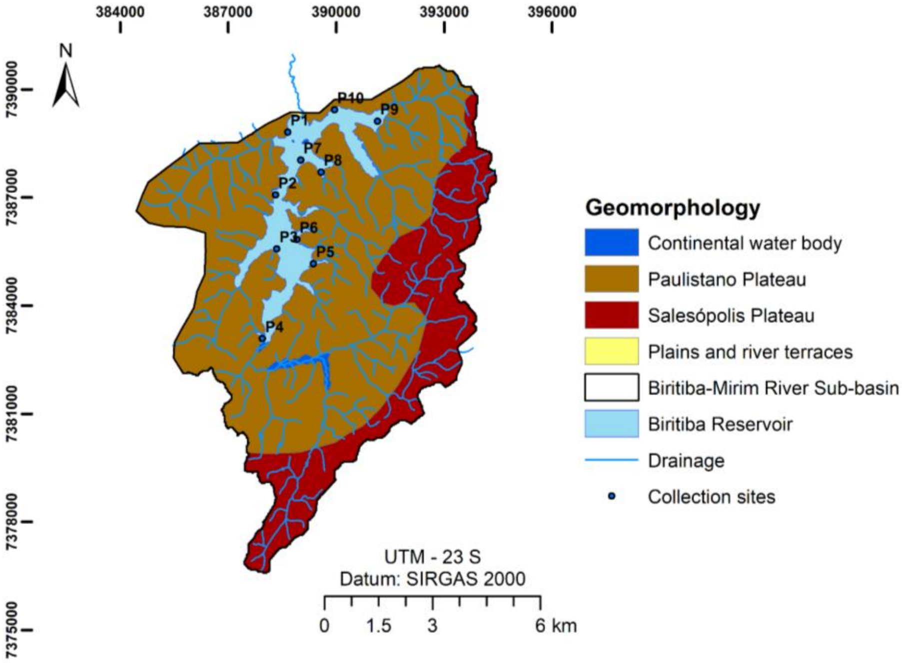
In terms of geomorphological formation, there is the Paulistano Plateau for the most part and the Salesópolis Plateau on the eastern and southern edges (Figure 6).

Figure 6 – Morphological map of the Biritiba Mirim reservoir

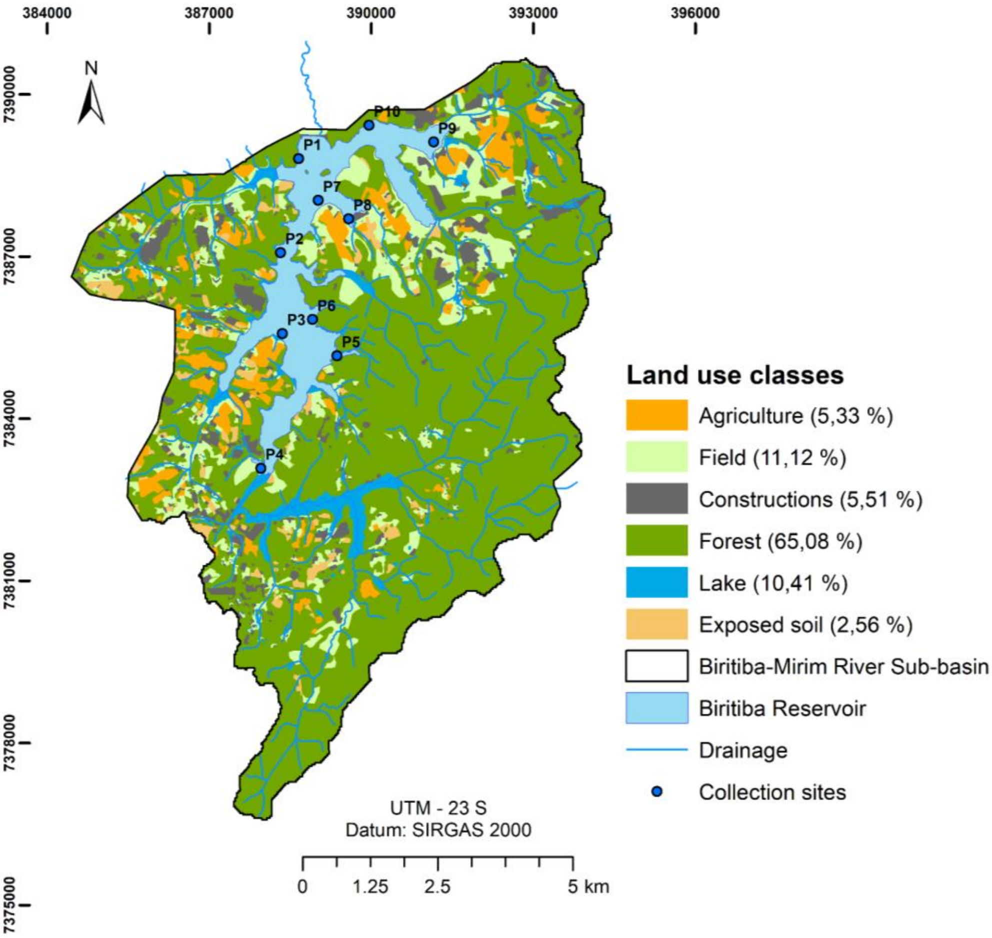


Source: Based on data by the authors.

3.2 Analysis of Land Use and Occupation

The Biritiba Mirim basin reservoir has features of a rural basin with five land use classes identified (Figure 7). The class of forest cover best represents the basin, corresponding to 65.08% of the land use; however, 24.5% of the occupied area in the basin correspond to disturbed areas, which are distributed as follows: 5.33% for agriculture, 5.5% for rural constructions, 2.56% for exposed soils that will be replanted, and 11.12% of field area that were used for agriculture and are now covered with grasses and eucalyptus.

Figure 7 - Map of land use and occupation around the basin of the Biritiba Mirim reservoir with the location of the sampling sites



Source: Based on data by the authors.

3.3 Analysis of limnological variables

The limnological features of water showed that most of the variables analyzed, except for total phosphorus, *E. coli*, and BOD, are within the limits established by the state resolution 10.755/77 for Class-1 freshwater bodies, which is the classification of the Biritiba Mirim reservoir (SÃO PAULO, 1977).

The values of phosphorus at two different areas in the dry season – August 2019 – varied from 23.73 total µg/L to 34.11 µg/L, that is, concentrations above the limit established by the CONAMA 357/05 de 20 µg/L (BRAZIL, 2005) and corresponding to mesotrophic environments (LAMPARELLI, 2004; PIRES et al., 2016) (Table 2).

The concentrations of total phosphorus were lower in the rainy season (from 17.12 µg/L to 24.11 µg/L), but the mesotrophic condition was preserved at sites 4, 5, 6, 9, and 10. It is worth highlighting that the higher values of total phosphorus total, in general, were recorded in the areas close to the crops, especially in the dry season (P 7 = 34.10 µg/L; P8 = 30.40 µg/L; P9 = 31.80 µg/L).

High concentrations of phosphorus in the water favor the growth of the phytoplankton community, whose biomass can be estimated based on chlorophyll *a*. The results of chlorophyll

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a corroborate such statement since higher concentrations of this variable, like with phosphorus, also occurred in the dry season, especially at stations 7, 8, 9, and 10.

Escherichia coli concentrations were absent at most sites analyzed in the dry season, being present only at stations 5 and 6, but with values below those established by CONAMA 357/2005 (120 UFC/100mL). In contrast, the bacterium was present at sites 3 (500 UFC/100mL), 4 (100 UFC/100mL), and 7 (1000 UFC/100mL) in the rainy season, with values much above those allowed by legislation at stations 3 and 7. Such a scenario occurs due to fecal contamination by animals since this bacterium usually lives in the intestines of mammals, like bovines, whose raising is common in rural areas close to the Biritiba Mirim reservoir. In addition, it is probably linked to the geomorphological features of the study area since stations 3 and 7 are close to the areas with the greatest slope that favor the drainage of these bacteria to the reservoir in the rainy season. Although some strains of *E. coli* are not pathogenic, others can cause severe gastrointestinal illnesses, such as enterohemorrhagic diseases, which are the most pathogenic for humans, highlighting the importance of managing the use and occupation of the land around the reservoir to maintain water quality (SOUZA et al., 2016).

The BOD concentrations in the dry season were below the detection limit at most sites analyzed; however, they significantly increased in the rainy season, probably due to the loading of organic matter to the water body, thus enhancing organic matter decomposition, especially at stations 2 (22.5 mg/L) and 5 (3.2 mg/L), which presented values above the limit CONAMA 357/2005 (<3 mg/L). Such a scenario is corroborated by the pH values, obtained in the rainy season, and DO, with lower concentrations in the dry season.

In general, the results suggest that in addition to the soil use in the surroundings of the reservoir, the geomorphological features of the region, and seasonality, the hydrodynamic features of the reservoir also influence water quality in this water body. Stations 7, 8, 9, and 10 showed the highest concentrations of total phosphorus and total nitrogen in a portion of the reservoir with lower water flow, thus favoring the accumulation of these nutrients in the environment.

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Table 2 – Mean values and standard deviation of the limnological variables of the Biritiba Mirim reservoir over the seasonal cycle (August and November 2019 and February and May 2020) (n = 4).

	S1 MC	S2 MC	S3 AG	S4 AG	S5 MC	S6 MC	S7 AG	S8 AG	S9 AG	S10 MC	CONAMA 357/2005
Trans	1.49±0.02	1.41±0,1	1.28±0,3	1.33±0.1	1.45±0,3	1.35±0,1	1.41±0,1	1.32±0,2	1.50±0,1	1.63±0,1	---
TN	407.4±26.8	395.6±13.1	430.3±16,2	476.1±23.4	434.6±15,6	427.8±18,1	327.1±2,1	427.7±27,4	314.8±31,6	366.8±46.1	---
NH_4	0.39±0.1	0.40±0,0	0,43±0,1	0.48±0.1	0,43±0,0	0.42±0,0	0.32±0,0	0.41±0,1	0.29±0,1	0.34±0.1	< 3.7
NO_2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	< 1.0
NO_3	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	< 10.0
TP	18.01±0.1	18.07±0.1	17.26±0.2	**21.35±0.6**	**21.79±0.9**	**21.01±0.2**	19.67±1.3	19.04±1.3	**23.65±0.5**	**21.51±0.7**	< 20
PO_4	5.70±1.4	4.96±0.9	4.78±0.8	5.01±1.7	6.9±2.0	7.30±3,2	7.90±4,2	7.23±3,4	7.73±2,9	6.86±2.4	---
Cl a	2.00±0.2	2.26±0.3	2.38±0.4	2.36±0.4	1.85±0,1	1.9±0.2	3.04±1,0	2.81±0,9	2.85±0,5	2.90±0.7	< 10
Alk	12.92±1.0	14.36±2.0	14.64±0.9	12.09±1.1	13.21±0.6	13.2±0.3	12.16±1.2	13.25±0.1	15.09±2.6	11.73±0.2	---
E. coli	6.3±12.5	1.3±2.5	**126.3±249.2**	31.3±47.3	13.8±24.3	12.5±25.0	**252.5±498.4**	5.0±10.0	17.5±23.6	17.5±35.0	< 120
BOD	0	**7.50±13.0**	0	0	**3.83±5.6**	0	1.20±1.4	0.70±1.2	0.90±1.6	1.20±1.2	< 3
pH	6.81±0.4	7.33±0.4	6.71±0.5	6.63±0.3	6.56±0,4	6.69±0.3	6.62±0.3	6.38±0.4	6.35±0.2	6.54±0.4	6 to 9
EC	49.75±4.2	49.5±4.4	49.5±4.5	43.25±3.3	47.25±4.0	47.5±4.7	49.25±3.8	50.50±4.182	57.00±5.6	51.75±3.4	---
Turb	2.4±1.8	1.13±0.1	1.2±0.2	3.23±3.7	1.1±0.0	1.0±0.2	1.17±0.3	3.43±4.4	1.20±0.2	1.00±0.3	< 40
DO	7.87±0.5	7.33±0.7	7.51±0.8	7.36±0.9	7.3±1.0	7.31±1.0	7.73±1.1	6.91±0.7	6.97±0.8	7.79±1.0	> 6
Temp	18.22±2.8	17.58±3.1	17.27±3.2	17.92±3.1	18.21±3.5	18.55±4.0	18.10±3.6	17.96±3.4	18.07±3.7	17.78±2.6	---
TS	0.03±0.0	0.03±0.0	0.03±0.0	0.03±0.0	0.03±0.0	0.03±0.0	0.13±0.2	0.03±0.0	0.04±0.0	0.03±0.0	---

Source: elaborated by the authors.

Note: Abbreviations: Trans (transparency) (m), TN (total nitrogen) (mg/L), NH4 (ammonium ion) (mg/L), NO2 (nitrite) (µg/L), NO3 (nitrate) (µg/L), TP (total phosphorus) (µg/L), PO4 (orthophosphate) (µg/L), Cl a (chlorophyll a) (µg/L), Alk (alkalinity) (mg/L), *E. coli* (*Escherichia coli*) (CFU/100mL), BOD (biochemical oxygen demand) (mg/L), EC (electrical conductivity) (µS/cm); Turb (turbidity) (NTU), DO (dissolved oxygen) (mg/L), Temp (temperature) (°C), and TS (total solids) (mg/L). *In bold are values above those recommended by CONAMA Resolution 357/05 for Class 1 lentic environments. RF = Riparian Forest; AG = Agriculture.

3.4 Environmental Indicators: Trophic State Index and Water Quality Index

The analysis of the Trophic State Index (TSI) classified all sampling stations as mesotrophic in the winter (except for stations 5 and 6), as well as stations 4, 7, 8, 9, and 10 in the fall (Figure 8A). In the rainy season (spring and summer), though, all sampling collections were classified as oligotrophic (Figure 8A).

Even though the sampling stations have similar trophic degrees, there is a trend of greater trophic values at the stations close to crop areas in such a portion of the reservoir.

These results indicate that the morphometric and hydrodynamic features of such a portion of the reservoir favors the accumulation of nutrients, thus causing worse trophic levels in the environment due to the input of fertilizers used on crops in the region from agricultural activities around the reservoir (TRINDADE, 2016).

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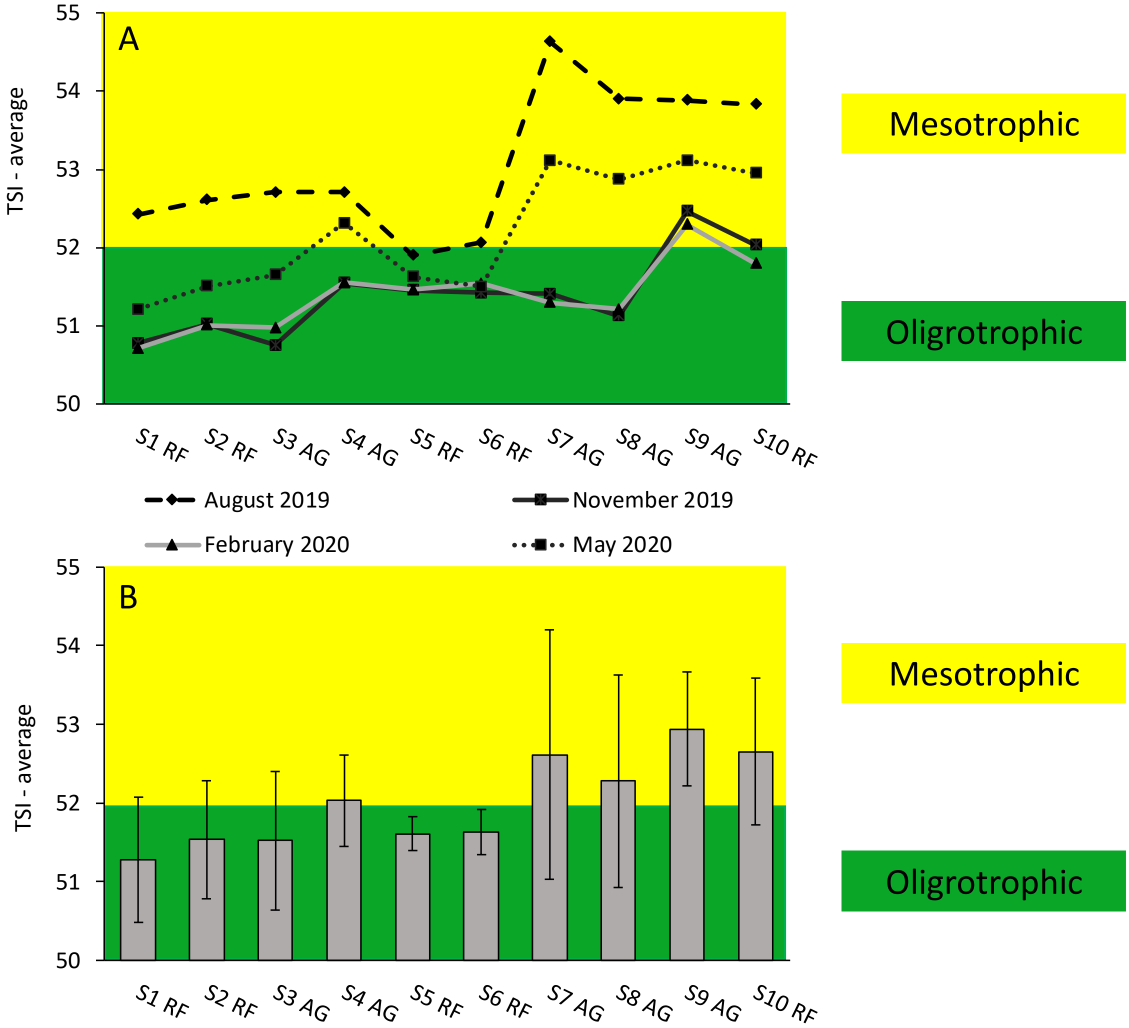
Figure 8 – Trophic State Index - TSI of the Biritiba Mirim reservoir in the ten different sampling stations analyzed. (A) variation of the TSI between sampling stations and collection periods. (B) mean values and standard deviation of the TSI values between the sampling stations.



Source: elaborated by the authors.

The results of the WQI classified the waters of the Biritiba Mirim reservoir as "EXCELLENT" for all sites analyzed in the dry season, as well as in the rainy season, except for sites 3 and 7, which were classified as "GOOD" (Figure 9).

Water quality at both these sites was damaged by fecal contamination, probably caused by the cattle raising in the reservoir surroundings. *E. coli* showed high concentrations at both sites and represented the variable of greatest weight for the WQI classification.

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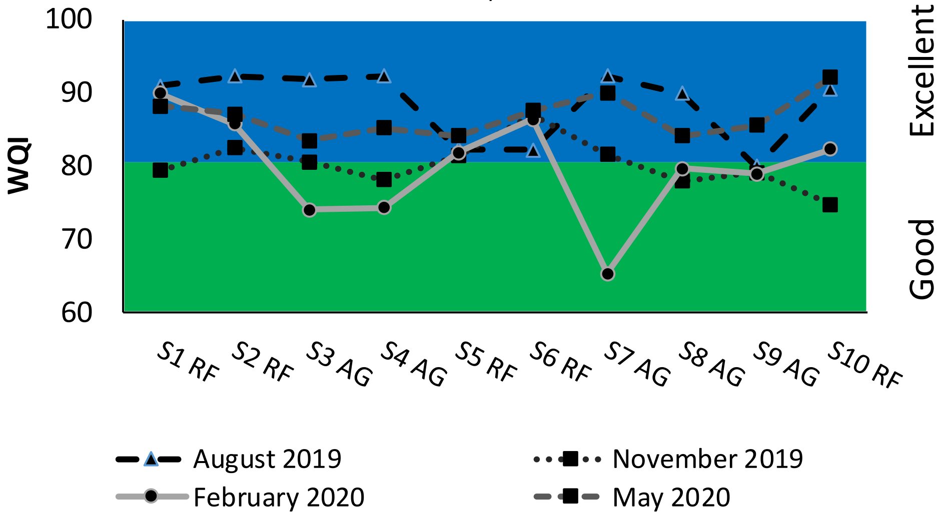
Figure 9 – Water Quality Index – WQI of the Biritiba Mirim reservoir in the ten different stations analyzed over a seasonal cycle



Source: elaborated by the authors.

Our results demonstrate the excellent water quality in the Biritiba Mirim reservoir; however, there were mesotrophic trends and conditions with signs of degradation derived from agricultural activities and animal raising.

Such signs increase in the portion of the reservoir whose hydrodynamic and morphometric features favor the nutrient accumulation and greater phytoplankton biomass, as well as in areas of the reservoir close to adjacent land with greater slope, which favors the drainage of allochthonous material to the reservoir in the rainy season.

4 CONCLUSION

The surrounds of the Biritiba Mirim reservoir have various land uses, with some more preserved areas covered by forests, representing 65.08% of the soil cover in the basin. However, rural land use is predominant, with 5.33% for crops, 5.5% for rural constructions, 2.56% for soil exposed by agricultural processes, and field areas covered by grasses and exotic vegetation (11.12%).

Such a rural use of the region leads to often higher concentrations of total phosphorus and *E. coli* than recommended by the current legislation, CONAMA 357/2005, notably at the sampling stations in the surrounding areas with agricultural activities.

Seasonality also seems to be a determining factor in studying the reservoir since the highest concentrations of PT and NO_2 occur in the winter. This should be a warning of the potential formation of algae and cyanobacteria blooms in subsequent months, which could restrict the use of water by local farmers and the abstraction of water for public supply.

Water quality indicators were shown to be a satisfactory tool for monitoring the reservoir, reflecting different soil use features, seasons, and morphometry.

Finally, we conclude that the good water quality in the Biritiba Mirim reservoir reflects the land use in its direct surroundings. In this context, this research might be updated by students and specialists in limnological and other related fields, in addition to being a reference

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for further studies in the research line for regions with similar features, or even government bodies that require specific data to develop public policies.

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5 REFERENCES

APHA - AMERICAN PUBLIC HEALTH ASSOCIATION. **Standard methods for the examination of water and wastewater**. 22nd. ed. Washington: American Public Health Association; American Water Works Association; Water Environment Federation, 2012.

BRASIL. CONSELHO NACIONAL DO MEIO AMBIENTE. (2005). Resolução CONAMA nº 357, de 17 de março de 2005. Dispõe sobre a classificação dos corpos de água e diretrizes ambientais para o seu enquadramento, bem como estabelece as condições e padrões de lançamento de efluentes, e dá outras providências. **Diário Oficial da União**: seção 1, Brasília, DF, n. 053, p. 58-63, 17 mar. 2005.

CETESB (SÃO PAULO). Guia nacional de coleta e preservação de amostras: água, sedimento, comunidades aquáticas e efluentes líquidos -Companhia Ambiental do Estado de São Paulo (CETESB). Organizadores: Carlos Jesus Brandão et al. São Paulo: CETESB; Brasília: ANA, 2011. 326 p.

CETESB - Companhia Ambiental do Estado de São Paulo. **Qualidade das águas superficiais no estado de São Paulo/ Apêndice D Índice de Qualidade de água**. São Paulo: CETESB, 2020.

ENGESAT. **Soluções em Imagens de Satélite e Geoprocessamento**. 2017. Disponível em: http://www.engesat.com.br/sentinel-2/. Acesso em: 07 ago. 2017.

GALLI, C. S.; ABE. D. S. Disponibilidade, poluição e eutrofização das águas. In: BICUDO, Carlos Eduardo de Mattos. TUNDISI. José Galisia. SCHEUENSTUHL. Marcos Cortesão. Barnsley (orgs.). **Águas do Brasil: Análises estratégicas.** São Paulo: Instituto de Botânica, 2010, pp. 165-174.

LAMAPARELLI, M. C. **Grau de trofia em corpos d’agua do Estado de São Paulo:** Avaliação dos métodos de monitoriamento. 238f. Tese (Doutorado em Ciências). Instituto de Biociências da Universidade de São Paulo, São Paulo. 2004.

MACKERETH, F. J. H.; HERON, J.; TALLING, J. F. **Water analysis: some revised methods for limnologist.** London: Freshwater Biological Association. 1978.

PIRES, D. A.; TUCCI, A.; CARVALHO, M. C.; LAMPARELLI, M. C. Water quality in four reservoirs of the metropolitan region of São Paulo, Brazil. **Acta Limnologica Brasiliensia**, v. 27, n. 4, p. 370-380, 2016.

SÃO PAULO. Decreto no 10.755, de 22 de novembro de 1977. Dispõe sobre o enquadramento dos corpos de água receptores na classificação prevista no Decreto no 8.468, de 8 de setembro de 1976, e dá providências correlatas. Diário Oficial do Estado de São Paulo, 1977.

SARTORI, A. C. **Qualidade Física e Química da água e sedimentos de fundo da porção SW do reservatório de Biritiba Mirim (SP) e sua implicação ambiental,** 2015. Dissertação (Mestrado em Hidrogeologia e Meio Ambiente) – Instituto de Geociências, Universidade de São Paulo, 2015.

SIRVINSKAS, L. P. **Manual de direito ambiental**. São Paulo: Saraiva Educação, 2020.

SOUZA, C. O; MELO, T. R. B.; MELO, C. S. B.; MENEZES, E. M. CARVALHO, A.C.; MONTEIRO, L. C. R. *Escherichia coli* enteropatogênica: uma categoria diarreiogênica versátil. **Revista Pan-Amazônica de Saúde,** v. 7, n.2, p.79-9, 2016.

ISSN 1980-0827 – Volume 19, Number 4, Year 2023

STRICKLAND, J. D.; PARSONS, T. R. A. A manual of seawater analysis. **Bulletin of the Fisheries Research Board of Canada**, 125: 1-185, 1960.

TRINDADE, C. S. **Relação entre a qualidade da água e sedimentos no reservatório de Biritiba-Mirim-SP face ao uso do solo em áreas sob vegetação natural e áreas agrícolas.** 239f.. Tese (Doutorado em Ciência Ambiental). Instituto de Energia e Meio Ambiente, Universidade de São Paulo, São Paulo. 2016.

VALDERRAMA, G. C. The simultaneous analysis of total nitrogen and total phosphorus in natural waters. **Marine Chemistry.** v. 10, p.109-122, 1981.

VELP CIENTIFICA. **BOD Analysis**. 2016. Disponível em: http://www.velp.com/en/products/lines/2/family/31/bod_analysis. Acesso em: 14 abr. 2016.

WETZEL, R. G.; LIKENS, G. E. **Limnological analysis.** New York: Springer-Verlag, 2000.

WHATELY, M.; DINIZ, L.T. **Água e esgoto na grande São Paulo: situação atual, nova lei de saneamento e programas governamentais propostos.** São Paulo: Instituto Socioambiental, 2009.