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Water Quality Assessment in the Córrego Taquara do Reino Hydrographic Basin, Guarulhos Municipality (São Paulo State - Brazil): Effects of Environmental Degradation

Avaliação da Qualidade da Água da Bacia Hidrográfica do Córrego Taquara do Reino, Município de Guarulhos (SP): Efeitos da Degradação Ambiental

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Resumo

A finalidade dessa pesquisa é avaliar a qualidade da água da bacia hidrográfica do Córrego Taquara do Reino, localizada no município de Guarulhos (SP), numa extensão de aproximadamente 800m, partindo da sua nascente até o exutório, no período compreendido entre maio de 2013 a março de 2014, em função da ocupação urbana na região. Foram coletadas amostras de água em três diferentes pontos e utilizaram-se para fins de análise os seguintes parâmetros físico-químicos e microbiológicos: fósforo total (Pt), demanda química de oxigênio (DQO), oxigênio dissolvido (OD), potencial hidrogeniônico (pH), condutividade elétrica (CE), temperatura, turbidez e coliformes fecais (*Escherichia coli*). Os resultados demonstram o elevado grau de degradação ambiental do Córrego Taquara do Reino que parte de um estado ultraoligotrófico em sua nascente, ponto 1, para um estado hipereutrófico no seu exutório, ponto 3, e também no ponto 2. Os demais resultados dos parâmetros físico-químicos como oxigênio dissolvido, turbidez e condutividade elétrica confirmam a diminuição da qualidade da água nos pontos 2 e 3. Os parâmetros fósforo total e *E. coli*, para os pontos 2 e 3 apresentam-se acima do limite estabelecido pela legislação CONAMA 357/05 para um corpo hídrico de classe 3. Observa-se correlação da condutividade elétrica com os parâmetros de fósforo total e *E. coli*, o que possibilita o uso desta medida como análise imediata da qualidade da água na bacia estudada.
Palavras-chave: São Paulo; impacto ambiental; índice de estado trófico

Abstract

The aim of this research is to assess the water quality in the Córrego Taquara do Reino hydrographic basin, located in the Guarulhos Municipality (São Paulo State – Brazil). The study area is a segment of approximately 800 m, from the Córrego Taquara do Reino spring to its outfall. Water samples were collected from May 2013 to March 2014 in three different points. The following physical-chemical and microbiological parameters were analyzed in the field and in the laboratory: total phosphorous (Pt), chemical oxygen demand (COD), dissolved oxygen (DO), hydrogen potential (pH), electric conductivity (EC), temperature, turbidity and fecal coliforms (*Escherichia coli*). The results show a high degree of environmental degradation in the Córrego Taquara do Reino basin, which progresses from an ultra-oligotrophic state in its headwaters, point 1, to a hypereutrophic state in its outfall, point 3, and also in point 2, as a function of the urban occupation in the region. The other results obtained for the physical-chemical parameters such as dissolved oxygen, turbidity and electric conductivity confirm the decrease in water quality in points 2 and 3. Total phosphorous and *E. coli* values found in points 2 and 3 are above the limit established by the CONAMA 357/05 legislation for a class 3 water body. A linear correlation between electric conductivity and total phosphorous and *E. coli* is observed, which enables the use of this parameter for a quick evaluation of the water quality in the basin.
Keywords: São Paulo; environmental impact; trophic state index

1 Introduction

Very recently, the Southern Region of Brazil, in special the São Paulo Metropolitan Region (RMSP), has undergone a severe drought. As a consequence, there has been a shortage in public water supply, as consumption has been greater than availability.

The disordered population growth, including areas under environmental protection, leads to a modification of the natural landscape elements, such as soil, relief forms, vegetation, fauna, hydrography, air, and climate (Braga, 2003).

Among the multiple uses, water supply for domestic use, watering livestock, irrigation, industrial processes, electric energy production, navigation for products and people transport, and environmental conservation stand out. In an integrated geo-environmental analysis of any hydrographic basin, it is necessary to weigh the impacts of different land uses on water quality, such as: the presence of biological or chemical contamination, changes in water temperature, and impacts in aquatic or riparian flora and fauna, among others. What happens in a hydrographic basin is a consequence of territorial occupation forms and the water uses that converge there (Tucci, 1997).

In the last years, research dedicated to the study of the Guarulhos municipality from a geoenvironmental analysis perspective calls attention to the fact that the urbanization model adopted for this municipality resulted in an environmental degradation process that affected a large area of the neighborhoods and allotments located in its northern portion (Saad *et al.*, 2013). In this sector of the municipality, relief units are composed of ridges, high and low hills, whereas hillocks, mounds and fluvial plains predominate in the southern part. With steep slope terrains inadequate to urbanization from the geotechnical standpoint, a disordered urban expansion prevails, with formal and informal allotments that are quite often clandestine. In the southern part of Guarulhos, the areas are flatter and with easier access, and the urbanization process started in this area. At present, this region is densely occupied with houses and industries at the margins of the major highways, and international airport, among other classes of land use (Andrade & Oliveira, 2008).

In general, when urban expansion reaches spring water catchment areas, water quality gets worse, mainly when urban residues and sewage are launched directly into rivers and reservoirs. Therefore, in this Urban Waters context (Tucci, 2008), the Córrego Taquara do Reino hydrographic basin constitutes an appropriate example for studies directed to the consequences of water quality in face of land use and of precarious socio-environmental conditions that exist in this portion of the Guarulhos municipality.

The objective of the present research is to assess the quality of the Córrego Taquara do Reino waters as a function of the environmental degradation caused by the Recreio São Jorge and Jardim Novo Recreio allotments, located in the Córrego Taquara do Reino hydrographic basin. To obtain the physical-chemical parameters necessary for this study, three points were analyzed for total phosphorous (Pt), pH, temperature, dissolved oxygen (OD), and chemical oxygen demand (COD), besides the microbiological parameter, *Escherichia coli*, from May 2013 to March 2014. The results were analyzed with basis on CONAMA Resolution 357/05 (BRASIL, 2005).

2 Material and Methods

The Taquara do Reino hydrographic basin, located in the central-northern portion of the Guarulhos municipality, belongs to the Cachoeirinha-Invernada hydrographic basin. The Recreio São Jorge and Jardim Novo Recreio allotments are located in the Taquara do Reino basin, in the Invernada neighborhood (Figure 1). The main morphometric parameters of this basin are listed in Table 1.

The points selected for the study include the main spring – point 1, and points 2 and 3, which correspond to the Recreio São Jorge and Jardim Novo Recreio urban occupations respectively. The points where chosen so that the Córrego Taquara do Reino topographic profile and different densities of urban land use are encompassed at the same time. The sampling points and corresponding UTM coordinates are described below:

- Point 1: Spring, UTM Coordinates – 345240 W / 7411570 S; altitude 820m;

- Point 2: Intermediate, UTM Coordinates – 345534 W / 7411257 S; altitude 790m;

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- Point 3: Outfall, UTM Coordinates – 345834 W / 7411055 S; altitude 780m.

The samples were collected using a simple sampling system every two months, summing up six samples from May 2013 to March 2014, in compliance with the standards established by the National Guide for Collection and Preservation of Samples (CETESB, 2003). The following parameters (equipment) were measured in the field: dissolved oxygen (Digimed DM-4), electric conductivity (Digimed DM-3), pH (Digimed DM-2), and turbidity (Quimis Q279P). To obtain the parameters total phosphorus, *Escherichia coli* and chemical oxygen demand (COD), the analyses were duplicated and carried out in the Laboratory for Water Analysis of the University of Guarulhos (UnG), following the APHA method (1995).Themethod

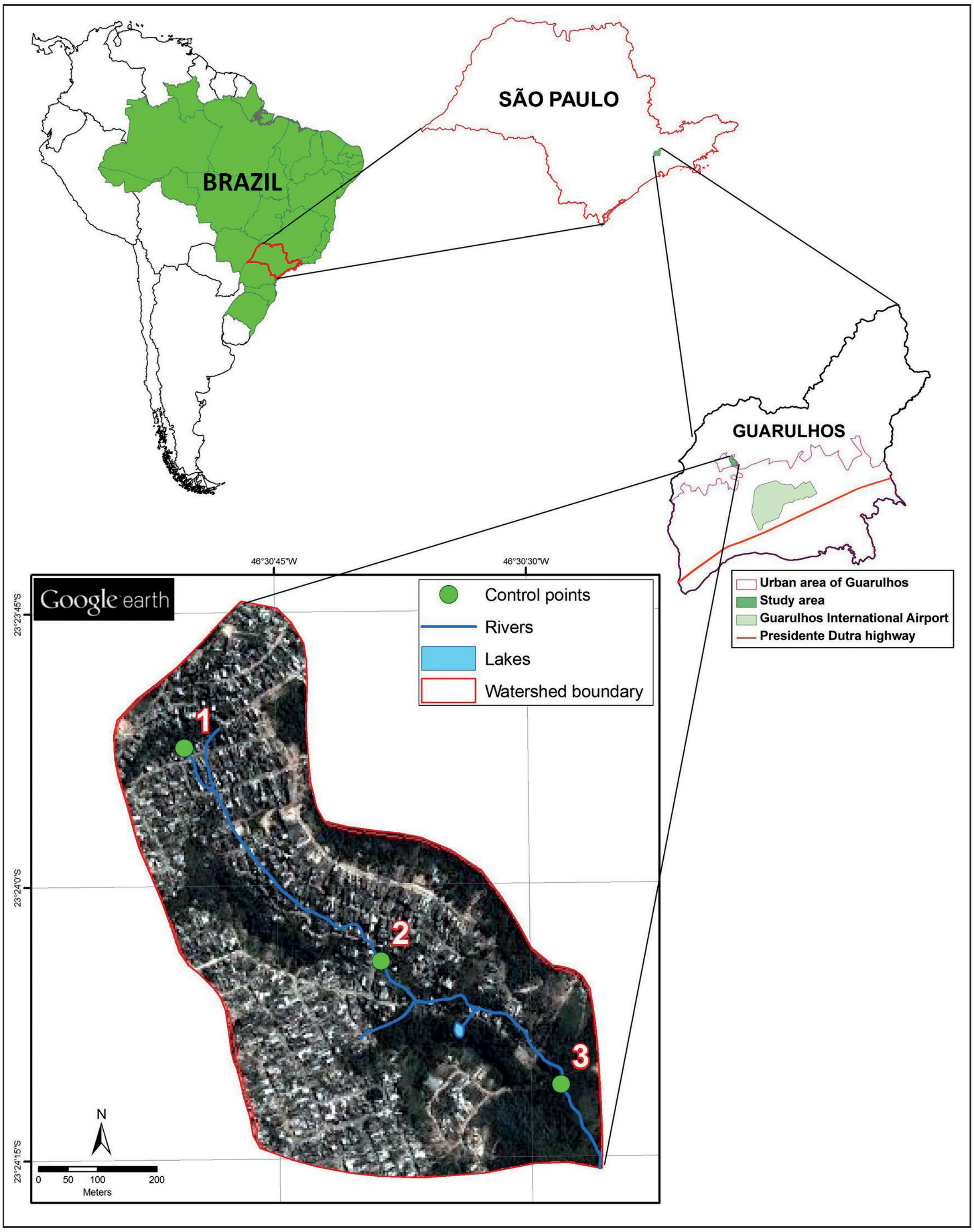

Figure 1 Location of the study area – Córrego Taquara do Reino hydrographic basin.

GEOMETRIC CHARACTERISTICS	
Area	43.82 ha
Perimeter	2973.73 m
Length	1090 m
Maximum width	580 m
Maximum altitude	880 m
Minimum altitude	770 m
Amplitude	110 m
Minimum declivity	4%
Maximum declivity	65%
MORPHOMETRIC INDICES	
Length of the drainage net	1392 km
Length of the main thalweg	1128.10 km
Declivity of the main thalweg	4%
Circularity	0.62
Drainage density	3.17 km/km^2
Thalweg gap	45 m

Table 1 Morphometric parameters of the Córrego Taquara do Reino hydrographic basin (Sato, 2008).

used by CETESB, to calculate and classify the trophic state index (TSI), introduced by Carlson (1977) and later modified by Lamparelli (2004), was adopted. The highest phosphorus and lowest chlorophyll a concentrations are found in lotic environments. In these environments, chlorophyll a may not be quantified, due to the large water volume in comparison to the marginal region, and also high water speeds (Farage *et al*., 2010; Saad *et al*., 2013). In the study area, for a lotic environment of great declivity, TSI was calculated only using phosphorus concentrations, according to Equation 1 (CETESB, 2009).

$$TSI = 10x(6-((0.42-0,36x (\ln Pt))/\ln 2))-20 \qquad (1)$$

where: Pt = total phosphorus concentration in water (μgL^{-1})

3 Results and Discussion

The Recreio São Jorge and Jardim Novo Recreio allotments have many improperly paved roads, making some of them impassable during intense rainfall; the maintenance of public services for all the population may be difficult, due to the high declivity of the terrain. Public services are restricted to the higher areas, where commerce, public transportation and collection of garbage are more intense. The allotments present several environmental problems, such as lack of basic sanitation, litter on river banks and different forms of erosion processes. Having this geo-environmental scenario in mind, a map of environmental degradation was prepared for the Córrego Taquara do Reino hydrographic basin (Figure 2).

In order to prepare the map of environmental degradation, a classification key with three levels was created, considering the assessment of the environmental damage caused by natural or induced phenomena, as proposed by IPT (1994), and regarding the anthropic actions in face of the incorrect soil handling:

- Areas degraded by induced natural processes;
- Areas degraded by occupation or improper management of the soil;
- Environmentally stable or regular areas.

In the first class, erosion in grooves and ravines, laminar erosion, landsliding and siltation deposits are included. In the second, there is the improper disposal of urban residues, urban occupation and rural management in Permanent Preservation Areas – PPA, and non-consolidated precarious urban occupation. The third class is related to preserved areas with forests, eucalyptus silviculture and small farms in areas outside the PPA.

According to São Paulo State decree number 10755, dated November 22nd, 1977 (SÃO PAULO, 1977), which establishes the classification of receiving water bodies, the Baquirivu Guaçu river and all its affluents fall in Class 3, which is also valid for Córrego Taquara do Reino. The only exception is the Tanque Grande reservoir and its affluents, which fall in Class 1.

The results from field analyses in points 1, 2 and 3 regarding the following parameters: pH, temperature, dissolved oxygen (DO), electric conductivity (EC), turbidity, and the values determined in the laboratory for total phosphorus (Pt) and *E. coli* are presented in Table 2. The limits established by the Resolution 357/2005 of the National Environmental Council (BRASIL, 2005) for Class 3 water bodies are also presented in the same table.

It is worth mentioning that, in terms of legislation, chemical oxygen demand (COD) and

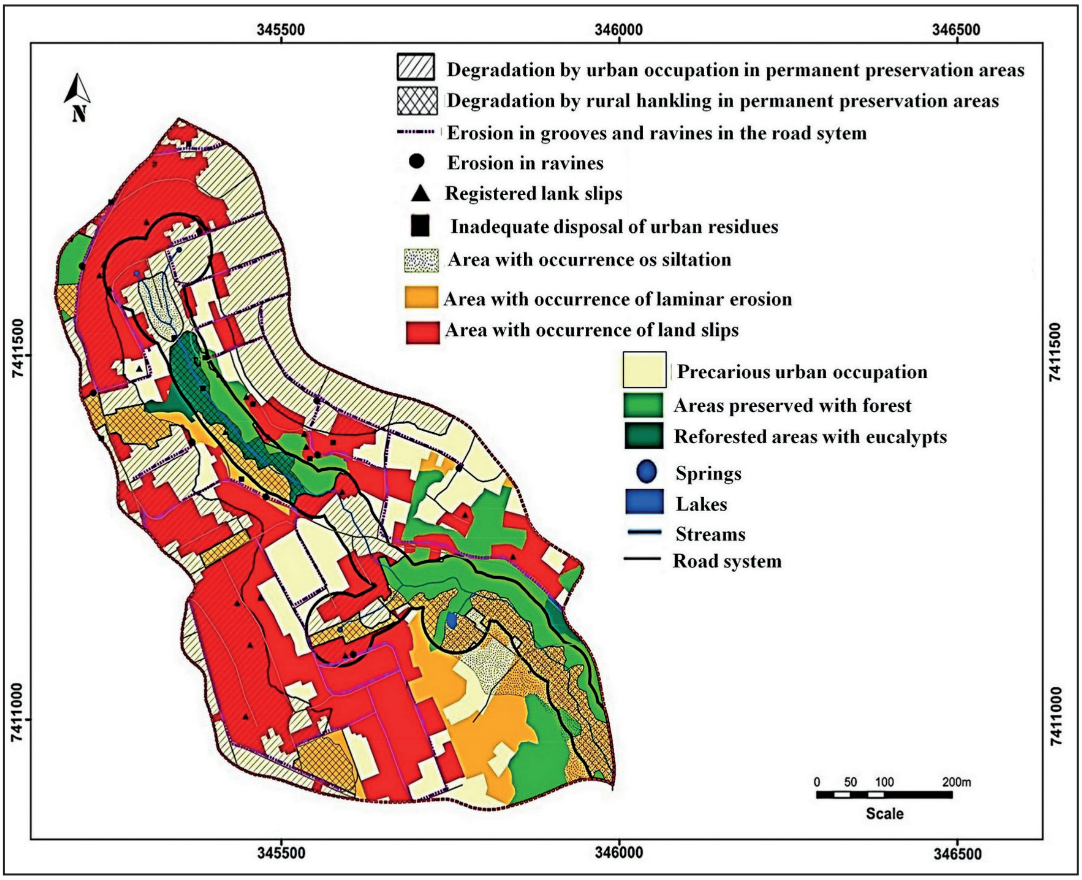

Figure 2 Environmental degradation map for the Córrego Taquara do Reino hydrographic basin.

electric conductivity (EC) are not used as water quality parameters. Still they are useful, because they can be related to parameters established by law for water bodies and can be used as indicators of degradation.

Phosphorus appears in natural waters mainly as a consequence of the sanitary sewage discharge (Sperling, 2005). Fecal organic matter and powder detergents used domestically in large scale constitute the main phosphorus source (Manahan, 2013). As observed in Table 2, total phosphorus analyses in points 2 and 3 revealed values well above the limit established by CONAMA 357/05 for a Class 3 water body. This demonstrates the lack of basic sanitation in the study area and the resulting impact in the environment. The trophic state index (TSI), even when calculated considering phosphorus only, is a measurement of the eutrophication potential of the environment, as this nutrient acts as a triggering agent for the process. According to the total phosphorus results obtained for points 1, 2 and 3 for the three months, TSI for point 1 corresponds to an ultra-oligotrophic state (Figure 3), that is, it is a clean water body, with very low productivity and insignificant nutrient concentrations. However, in points 2 and 3, a hypereutrophic state (Figure 3) is indicated, which means that the water bodies are significantly affected by high organic matter and nutrients concentrations, compromising their uses.

The results demonstrate that the Córrego Taquara do Reino comes from a naturally equilibrated environment, point 1, to a highly degraded environment, points 2 and 3. As the declivity of the hydrographic basin is high, the phosphorus charge is carried to the lower parts, reaching the Baquirivu-Guaçu river.

The electric conductivity (EC) expresses the capacity of the water to conduct an electric current, and therefore it is a function of salinity of water body. Several studies have reported the use of EC as a measure of the impact of pollutants in aquatic environments, such as rivers (Thompson *et al*., 2012) and lakes (Das *et al*., 2006; Costa & Henry, 2010). It is worth mentioning that the water electric conductivity (EC) depends on the rock types that

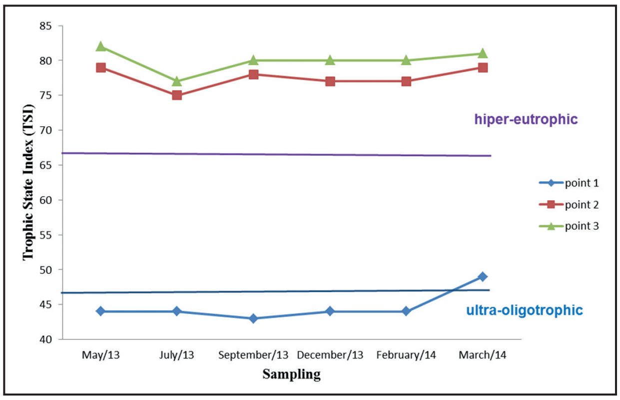

Figure 3 Córrego Taquara do Reino trophic state in points 1, 2 and 3 from May 2013 to March 2014.

it percolate, as well as the type of aquifer (free or confined), the anthropic actions, residence time, among others (Tong & Chen, 2002).

The EC determination, despite not predicted in the legislation, can represent an indirect measurement of pollutant concentrations. In this sense, the measurements carried out in points 1, 2 and 3 were correlated with the total phosphorus analyses, which, as previously seen, indicate extreme trophic levels. As in point 1 water is free from anthropic interference, the EC measured in this point can be used as a reference of quality standard. In fact, there is a linear correlation between the two parameters, the correlation coefficient resulting in 0.86. Even if a large number of data is necessary for such study, which should be extended to other hydrographic basins of the region, this preliminary result can be taken as a quick check and can help assess the quality of the water body. A similar correlation was obtained when the logarithmic function of the *E. coli* concentration and conductivity were analyzed, resulting in a correlation coefficient of 0.82.

Using the boxplot graphic analysis, it is observed that the conductivity values of the order of 190 μScm^{-1} correspond to a non-degraded water (Figure 4), whereas conductivity values greater than 300 μScm^{-1} indicate anthropic interference in the water body. According to Tong & Chen (2002), the characteristics of each type of soil and use imply in very distinct quantitative and qualitative characteristics of the runoff. A major dispersion of the EC values can be observed in points 2 and 3, due

Month	Point	pH	T	EC	DO	Turbidity	Total phosphorus	*E. coli*
			(ºC)	(mS/cm)	(mg/L)	(*UNT*)	(mgL^{-1})	(UFC 100mL^{-1})
May/13	1	6.5 ± 0.1	20.0 ± 0.1	199 ± 1	8.2 ± 0.1	0.3 ± 0.1	0.005 ± 0.000	1.0 ± 0.0
	2	7.7 ± 0.1	20.4 ± 0.2	339 ± 5	**3.8 ± 0.3**	97.3 ± 2.2	**1.46 ± 0.16**	**(1.65 ± 0.21) x 10^6**
	3	7.8 ± 0.1	20.6 ± 0.0	461 ± 2	5.0 ± 0.1	69.9 ± 3.8	**2.39 ± 0.13**	**(2.10 ± 0.14) x 10^6**
July/13	1	7.0 ± 0.1	19.3 ± 0.1	187 ± 1	7.5 ± 0.1	1.0 ± 0.0	0.005 ± 0.000	17 ± 2
	2	6.7 ± 0.1	16.8 ± 0.0	347 ± 2	7.6 ± 0.1	34.3 ± 1.2	**0.751 ± 0.071**	**(6.05 ± 0.35) x 10^6**
	3	7.0 ± 0.1	16.1 ± 0.2	393 ± 11	6.7 ± 0.5	23.7 ± 0.6	**1.04 ± 0.04**	**(4.55 ± 0.35) x 10^6**
September/13	1	6.5 ± 0.1	19.7 ± 0.1	179 ± 1	6.7 ± 0.1	0.2 ± 0.0	0.004 ± 0.000	Null
	2	7.6 ± 0.1	20.3 ± 0.1	304 ± 2	8.0 ± 0.1	41.7 ± 0.1	**1.32 ± 0.11**	**(3.15 ± 0.21) x 10^6**
	3	7.8 ± 0.1	20.0 ± 0.0	364 ± 1	9.8 ± 0.4	43.2 ± 0.1	**1.86 ± 0.13**	**(5.45 ± 0.35) x 10^6**
December/13	1	5.8 ± 0.0	20.2 ± 0.1	177 ± 1	4.4 ± 0.2	0.8 ± 0.0	0.005 ± 0.000	Null
	2	7.4 ± 0.1	21.9 ± 0.1	360 ± 2	**2.3 ± 0.4**	30.7 ± 0.3	**1.14 ± 0.01**	**(6.50 ± 0.14) x 10^4**
	3	7.7 ± 0.1	22.9 ± 0.0	445 ± 1	**1.3 ± 0.1**	29.8 ± 0.2	**1.84 ± 0.03**	**(1.30 ± 0.14) x 10^6**
February/14	1	6.0 ± 0.1	21.1 ± 0.1	183 ± 2	6.0 ± 0.1	0.3 ± 0.0	0.005 ± 0.000	Null
	2	7.5 ± 0.1	23.2 ± 0.1	345 ± 2	4.5 ± 0.5	34.7 ± 1.4	**1.06 ± 0.01**	**(1.50 ± 0.28) x 10^5**
	3	7.7 ± 0.1	23.4 ± 0.2	457 ± 0	**3.8 ± 0.5**	86.7 ± 30	**1.72 ± 0.04**	**(3.00 ± 0.28) x 10^5**
March/14	1	6.2 ± 0.0	20.4 ± 0.1	205 ± 1	7.8 ± 0.3	0.6 ± 0.1	0.011 ± 0.001	Null
	2	7.8 ± 0.1	21.3 ± 0.1	386 ± 1	**1.7 ± 0.1**	50.7 ± 3.4	**1.49 ± 0.01**	**(5.05 ± 0.07) x 10^5**
	3	8.0 ± 0.1	21.4 ± 0.1	449 ± 1	**2.1 ± 0.2**	52.1 ± 2.1	**2.00 ± 0.27**	**(2.15 ± 0.07) x 10^6**

Table 2 Values of physico-chemical and microbiological parameters for water samples, measured in the field and in the laboratory, and for CONAMA 357/05.

to the intermittent sewage launch in waters of the Córrego Taquara do Reino (Figure 4), fact that is not observed at point 1, because it is a spring.

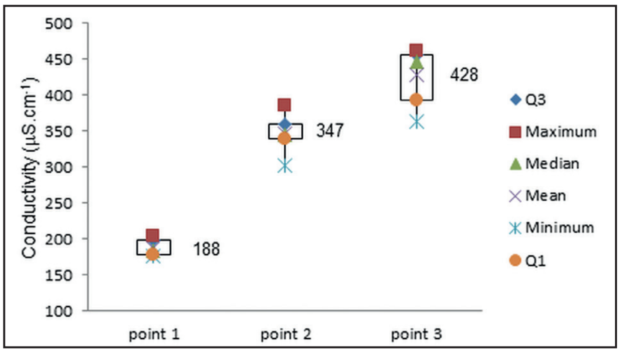

Figure 4 Boxplot of the electric conductivity of the Córrego Taquara do Reino water, with samples taken from May 2013 to March 2014.

Regarding dissolved oxygen, some measurements for points 2 and 3 were below the limit of 4.0 mgL^{-1} established by CONAMA 357/05. Despite a great quantity of domestic sewage is launched in this water body, the declivity of the terrain is high, which favors aeration. For September 2013, the dissolved oxygen values were high, because heavy rain fell in the study area on previous days, favoring water oxygenation.

The microbiological aspects of the Córrego Taquara do Reino waters were also considered, by the determination of the *E. coli* bacteria concentrations. The origin of this microorganism is exclusively fecal, as it is present in the human, mammals and birds feces, and is rarely found in water or soil not contaminated by such waste (Sperling, 2005). According to Table 2, extremely high values found in points 2 and 3 result from the direct discharge of domestic sewage in the water body, the values of *E. coli* concentrations being much higher than the limit established by CONAMA 357/05.

The organic matter inflow due to the lack of sanitation was also confirmed by the chemical oxygen demand (COD) values of 18, 65 and 73 found respectively in points 1, 2 and 3, which illustrate an increase in organic matter content along the basin.

Despite the water supply by SAAE (*Serviço Autônomo de Água e Esgoto* – Autonomous Service for Water and Sewage for the Guarulhos municipality), the local community in the Recreio São Jorge and Jardim Novo Recreio allotments uses water from point 1 for laundry, cooking and drinking. Fortunately, after a year of analyses, it was attested that the water in this point is not contaminated by feces. However, the lack of a collecting sewage network in the study area implies the contamination of the Córrego Taquara do Reino waters, representing a possible agent causing water borne diseases, in particular diseases that affect the human intestinal tract (Crapez, 2008).

4 Conclusion

The quality of the waters of the Córrego Taquara do Reino was studied from May 2013 to March 2014, in order to assess the environmental degradation conditions observed in plots of the Recreio São Jorge and Jardim Novo Recreio, due to the fact that the physical environment present limitations for urban occupation, in special in areas of high declivity (Sato, 2008). Thus, areas degraded by induced natural processes were identified, materialized by different environmental impact forms.

A second class of degraded areas is that with occupation or improper management of the soil, where precarious urban occupation, improper solid residue disposal and lack of sewage collecting net, as the main causes of environmental damage.

By analyzing physical-chemical and microbiological parameters measured in the field and in the laboratory for three different points, a high degree of environmental degradation was attested for the Córrego Taquara do Reino, which comes from an ultra-oligotrophic state in its spring, point 1, to a hypereutrophic state in its outfall, point 3. The microbiological parameter *Escherichia coli* helped understand the fecal contamination of the water body, implying in severe contamination risk to the local community. The other physical-chemical parameters, such as dissolved oxygen, turbidity and electric conductivity, confirmed the decrease in water quality in points 2 and 3. A correlation between electric conductivity and total phosphorus and *E. coli* was observed, which attests for the use of this parameter as a measure of the water quality in the study area.

In face of this environmental degradation context, the idea that the solid residues accumulated in the slopes and drainages, associated with the lack of sewage, are the main conditioning factors of water quality is ratified, on the basis of the selected parameters.

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