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ANALYSIS OF THE WATER QUALITY INDEX OF THE NEGRO AND RESENDE RIVERS IN DUAS BARRAS DISTRICT, RIO DE JANEIRO (BRAZIL)

ISABELLA ROBERT RODRIGUES[1], MAURO CÉSAR GERALDES[1*], ANDRÉA ALVES FERREIRA[1], MARCELO DOS SANTOS SALOMÃO[1] AND SÉRGIO VIEIRA ANVERSA[2]

1 Universidade do Estado do Rio de Janeiro, Faculdade de Geologia, Rio de Janeiro, Brazil.
2 Universidade Castelo Branco, Rio de Janeiro, Brazil.

* CORRESPONDING AUTHOR, mauro.geraldes@gmail.com

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Abstract

In Brazil, about 49% of the population does not have access to the sewage collection network, with the consequent direct discharge of their sewage network into water bodies. Due to this scenario, it is essential to investigate the quality of the water consumed by thousands of people along the Negro and Resende Rivers. The present study analysis the waters of the Negro and Resende rivers, located in Dois Rios River Basin, in the municipality of Duas Barras, Rio de Janeiro State (RJ, SE Brazil), based on the Water Quality Index proposed by the National Sanitation Foundation (United States). The population of the district located in the municipality of Duas Barras dumps the domestic sewage directly into the hydrographic network. The analyzed parameters were: turbidity, Total Residue, total phosphorus, total nitrogen, biochemical oxygen demand (BOD), hydrogenation potential, temperature, dissolved oxygen and thermotolerant coliforms. The values obtained from the calculation of the Water Quality Index (WQI) showed a variation from 40 to 68, meaning that the quality of water vary between bad and acceptable in the study area. The samples collected in the urban area contained values for thermotolerant coliforms in disagreement with the maximum value permissible for classes 2 and 3 of fresh water by CONAMA (Conselho Nacional do Meio Ambiente; a Brazilian Council for the Environment) Resolution 357/2005. The results of the analyzes confirmed the contamination of the two rivers by the discharge of domestic effluents, showing that actions are necessary to eliminate or minimize the discharge of sewage in the surveyed water bodies, since it may cause public health risks.

Keywords: Water Quality Index. Contamination of Rivers. Domestic Effluents. Thermotolerant Coliform.

1 Introduction

Water is one of the essential elements to life and the most abundant substance on the Earth surface. It is also the best and most common solvent found in nature and plays a fundamental role in weathering and relief formation. Its occurrence is distributed in oceans, glaciers, rivers, lakes and underground. However, surface freshwater represents approximately 0.03% of all water in the world (Brown and Bhushan, 2016).

Water with good quality is indispensable for the maintenance of human, animal and environmental health. The inadequate fate of waste and effluents and the degradation and /or occupation of riparian forests affect the availability and quality of water resources. Pollution compromises its use in different activities and supply and is also an important aspect in the dissemination of vectors and diseases such as bacillary dysentery, typhoid and cholera (ANA, 2017).

Control of water pollution is of utmost importance to developed and developing countries. Measures such as prevention of pollution at its source, the precautionary principle and prior licensing of effluent disposal are key elements of policy-making to prevent, control and reduce the introduction of hazardous substances, nutrients and other pollutants into aquatic ecosystems. Hazardous pollutants are toxic substances at low concentrations, carcinogenic, mutagenic, and may have teratogenic and /or bioaccumulative effects, especially when they are persistent (Helmer and Hespanhol, 1997).

Water quality is assessed through biological, physical and chemical parameters. The maximum limits of these parameters are established by national and international agencies, and by laws, regulations and standards, which consider the local peculiarity. This is why there are so many specific indexes to each region or area.

The Arithmetic Water Quality Index (Horton, 1965) was initially proposed in the United States in 1965. Subsequently, several assessment methods were formulated by different international organizations, with emphasis on the National Sanitation Foundation Water Quality Index (NSFWQI), based on the types and values of water quality parameters to meet the standards of a given region (Brown et al., 1970). NSFWQI is the most used index in the US. In Brazil, it was used as the basis for the adaptation that is being used by the Agência Nacional de Águas - ANA (National Water Agency; ANA, 2012).

Due to the increasing population growth and to the development of increasingly populated urban areas, there has been a significant acceleration in the degradation of water resources destined for use and consumption in the country (Santin and Corte, 2011).

Faced with these facts and the increasing diversification of pollution sources, it is necessary to evaluate the quality of the rivers' waters, in order to support environmental protection and recovery actions, in order to guarantee current and future uses. These actions should be part of an integrated water resources management plan, supported by government programs and policies.

In order to solve conflicts related to water uses and to base measures for the preservation or qualitative and quantitative recovery of rivers and watersheds, it is necessary to establish a water quality monitoring program. This should aim to evaluate their current conditions and characteristics, as well as provide information to support the decision making pertinent for the management of this resource.

The characterization of a spring to may be carried out by a qualitative study, elaborated through the analysis of samples that provide information on the physical, chemical and biological profiles of rivers and water bodies (Weinberg, 2013).

In Brazil, about 49% of the population does not have access to the sewage collection network (SNIS, 2017). The municipality of Duas Barras, in the Mountain Region of the Rio de Janeiro State, illustrates the reality of different cities in the country that discharge the sewage in rivers and water bodies. Despite the treatment of effluents from agglomeration centers such as condominiums, schools, nurseries and health units by fossa-filter systems (provided for ABNT NBR 7229 and 13969 for areas not provided by wastewater collection network), other sewage is discharged *in natura* resources. The region has no industries, a factor that characterizes the effluents as domestic. However, the organic load from homes and activities such as agriculture and livestock are potential sources of water contamination.

As the Duas Barras district has the peculiarity of harboring in its domain the springs of two of its main rivers (Negro and Resende rivers), it is imperative to investigate the quality of the water along these rivers, whose water is used for drinking by thousands of people who inhabit the locality and that later will supply, downstream, other municipalities.

This work provides a preliminary analysis of the water quality of the Negro and Resende rivers, estimating the contribution of the organic load discharged in the urban area of the Duas Barras district.

2. Study Area

The study area comprises the district that is the seat of the municipality located on the Instituto Brasileiro de Geografia e Estatistica (IBGE; Brazilian Institute of Geography and Statistics) Duas Barras topographic sheet, in the 1: 50,000 scale. It is located in the Serrana Region of the Rio de Janeiro State (Figure 1), and borders the municipalities of Bom Jardim, Cantagalo, Carmo, Cordeiro, Sumidouro and Nova Friburgo. In 2010, the census data (IBGE, 2018) recorded a population of 10,930 individuals and a population density of 29.14 inhabitants per km^2. The climate in the locality, because it is a mountain region, is classified as Tropical of Altitude (Köppen and Geiger, 1928), being common to present mild temperatures throughout the year, varying between 18 °C and 26 °C (Clima Date, 2017).

In the municipalities bordering the mountains, the average annual rainfall is over 2,000 mm (ANA, 2012). During the rainy season (November, December and January), the average rainfall is from 1254.1 mm to 1596.2 mm (Calderano et al., 2012).

The municipality of Duas Barras is distinguished by the presence of important waterbody springs, the Negro and Resende rivers. Dynamically, the Resende river flows into the Rio Negro and this river joins the Rio Grande. The union of these last two bodies of water is called Dois Rios river. The studied area belongs to the Mountain Region of the Rio de Janeiro State, being inserted in the Geomorphological Unit denominated Reverse of the Hills and Coastal Massifs of the Serra dos Órgãos Plateau. It presents a predominant domain of elevated hills and mountains with occurrence of smooth relief alveoli, subordinated to the mountainous domain (Calderano et al., 2010), whose relief varies from 500 to 900 meters of altitude.

The geological and geomorphological aspects directly reflect the drainage pattern, the water energy and the chemical parameters observed in the waters that percolate several lithotypes. For a better understanding of these aspects, it is necessary to contextualize the geological-tectonic history where the study area is inserted, as well as to present the lithotypes and the alluvial coverings that occur in the region.

The study area of this work is located in the Oriental Terrain of the Ribeira Belt (Figure 2), which includes magmatic arc rocks (Negro Rio Complex), migmatite gneisses (Cordeiro Suite) and neoproterozoic metassediments. The relief of the municipality of Duas Barras shows more devastated features, especially along the beds of the Negro and Resende rivers, where outcrop rocks of the Negro River Complex. In the higher topographic features, such as at the head of the Negro River, rocks of the Cordeiro Suite arise (Tupinambá, 2012).

3. Materials and Methods

The steps involved previous studies that included the recognition of the area and the subsequent sampling in six points (Table 1; Fig. 3), defined aiming to represent the particularities and occupation profile of the investigated hydric segments. The information obtained was analyzed and interpreted through a qualitative research using the adapted version of the Water Quality Index (WQI) created in 1970 in the United States by the National Sanitation Foundation. This adaptation was adopted by the Companhia de Tecnologia de Saneamento Ambiental - CETESB (Environmental Company of São Paulo State), which currently constitutes the main Water Quality Index used in the Brazil (ANA, 2017).

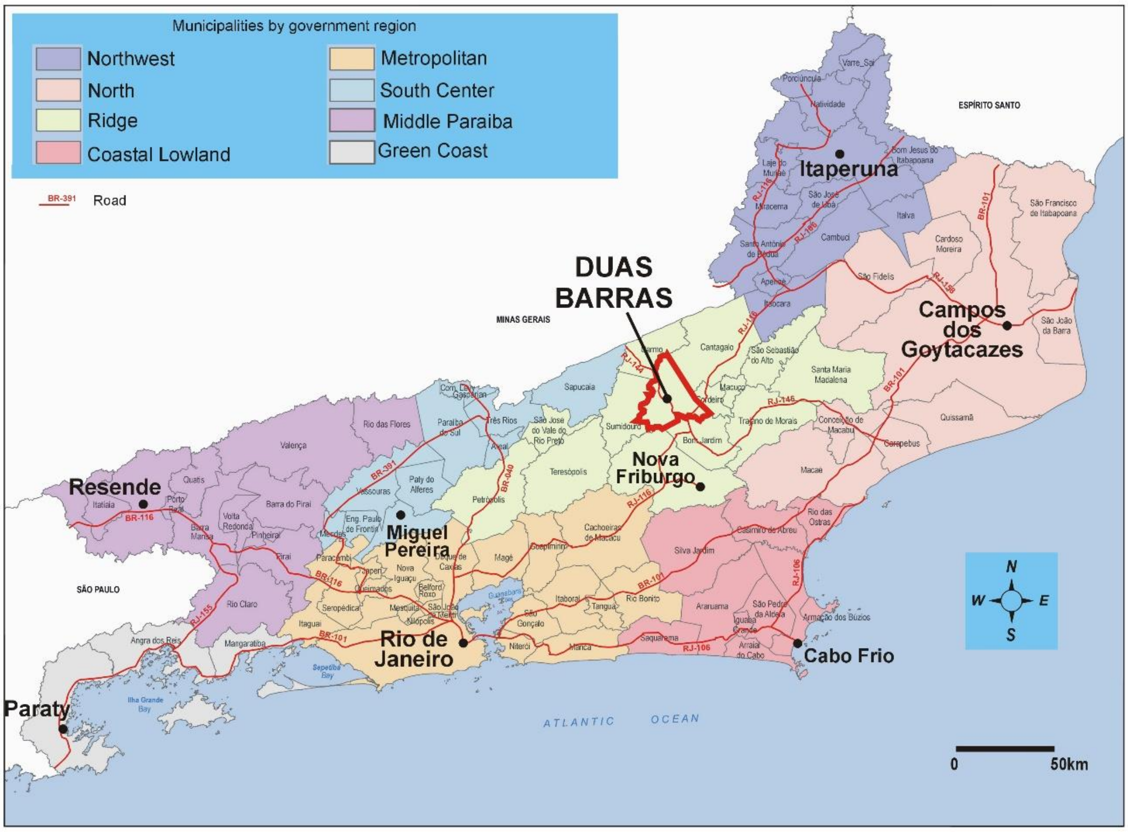

Fig. 1. Map of the Rio de Janeiro State, highlighting the headquarters district of Duas Barras and neighboring municipalities (modified from CEPERJ, 2014).

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Tab. 1. Coordinates of sampling points (Zone 23K, Datum WGS-84).

Point	Longitude	Latitude	Water Resource
1	42°32'10.19"	22° 2' 55.13"	Resende River
2	42°34'2.89"	22°9'18.63"	Negro River
3	42°31'12.57"	22°3'6.29"	Negro River
4	42°31'14.32"	22°3'4.074"	Resende River
5	42°30'27.18"	22°2'34.62"	Negro River
6	42°28'37.67"	22°1'33.47"	Negro River

The nine parameters that make part of the WQI calculation (Table 2) mainly reflect the degree of contamination of rivers and water bodies by the discharge of domestic sewage (ANA, 2012). In addition to the WQI, the standard values of the Conselho Nacional do Meio Ambiente - CONAMA (National Council for the Environment; CONAMA Resolution 357/2005) for Thermotolerant Coliforms and Biochemical Oxygen Demand (BOD) were also used, corresponding to the release of domestic effluents and the amount of consumed oxygen in the degradation of the organic matter in the aquatic environment. This strategy aims to establish a relationship between the released wastes and the levels of the analyzed parameters.

The WQI is calculated by means of the weighted output of the nine parameters, according to the formula (NSF, 2007):

$$WQI = \prod_{i=1}^{n} {q_i}^{w_i}$$

Where: WQI = Water Quality Index. A number between 0 and 100; qi = quality of the ith parameter. A number between 0 and 100, obtained from the respective quality chart, depending on its concentration or measurement (analysis result) and; wi = weight corresponding to the ith parameter set in function of its importance for the overall evaluation of the water quality, that is, a number between 0 and 1.

The data included in the formula are generated from the results of the analyzes and the weight of each parameter, fixed according to their importance for the overall evaluation of the water quality (Table 3). In the graph of variation of the parameters (Fig. 4), according to its concentration or measurement, a quality value (q) was assigned. The calculations were performed for each sampling point considering the nine parameters (Table 3), and the resulting values contained in ranges varying from "Very bad" to "Very good," as shown in Table 4.

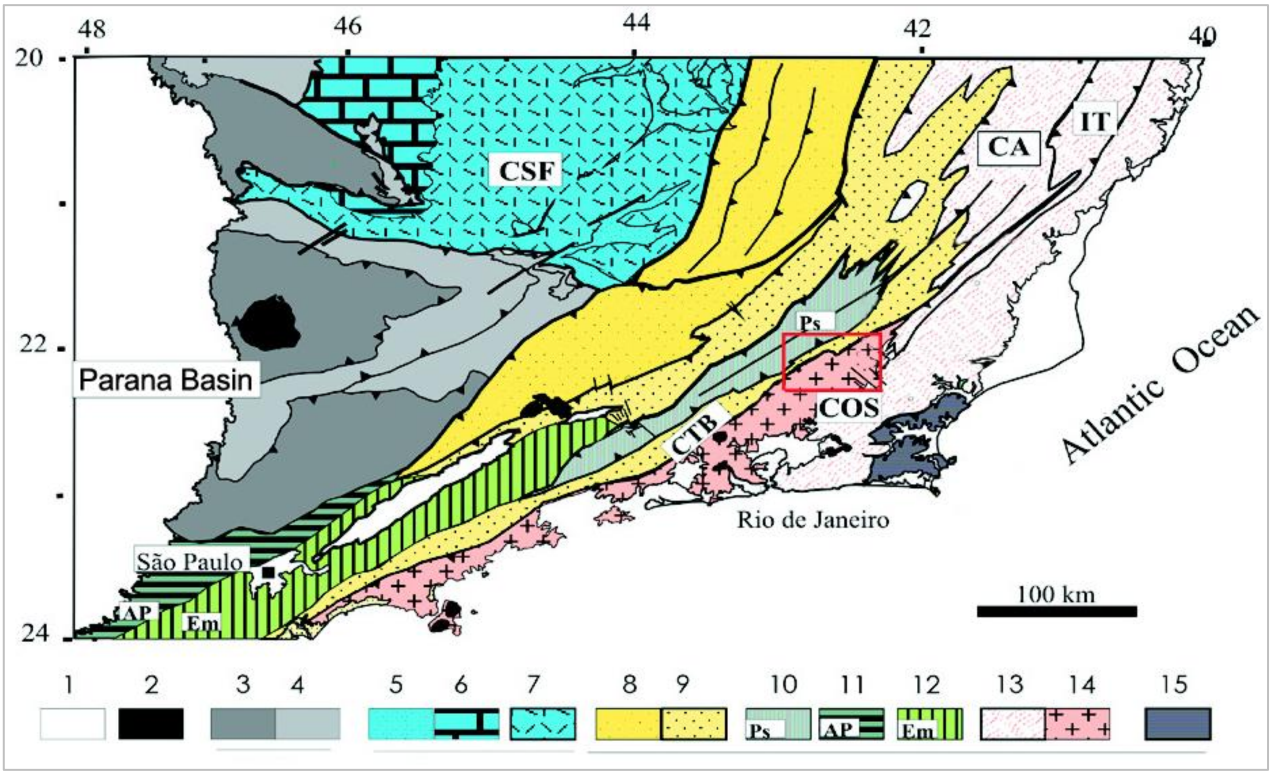

Fig. 2. Tectonic map of the Ribeira Belt in the southeast portion of Brazil, with emphasis on the region of the municipality of Duas Barras. 1) Paraná Basin and Cenozoic rifts / sediments; 2) Alkaline rocks of the Neo Cretaceous and Paleogene; Orogen Brasília; 3) External Domain; 4) Internal Domain; San Francisco Craton (CSF); 5) Autochthone Megasequence Andrelândia; 6) Bambuí Supergroup; 7) Cratonic basement; Orogen Ribeira: Occidental Terrain; 8) Domains Andrelândia and 9) - Juiz de Fora; 10) Paraíba do Sul Terrain; 11) Apiaí Terrain; 12) Embú Terrain; 13) Oriental Terrain (CA - Cambuci Domain; IT - Italva Klippe; COS - Costeiro Domain); 14) Oriental Terrain: Rio Negro Magmatic Arc; 15) Cabo Frio Terrain (Adapted from Heilbron et al., 2004).

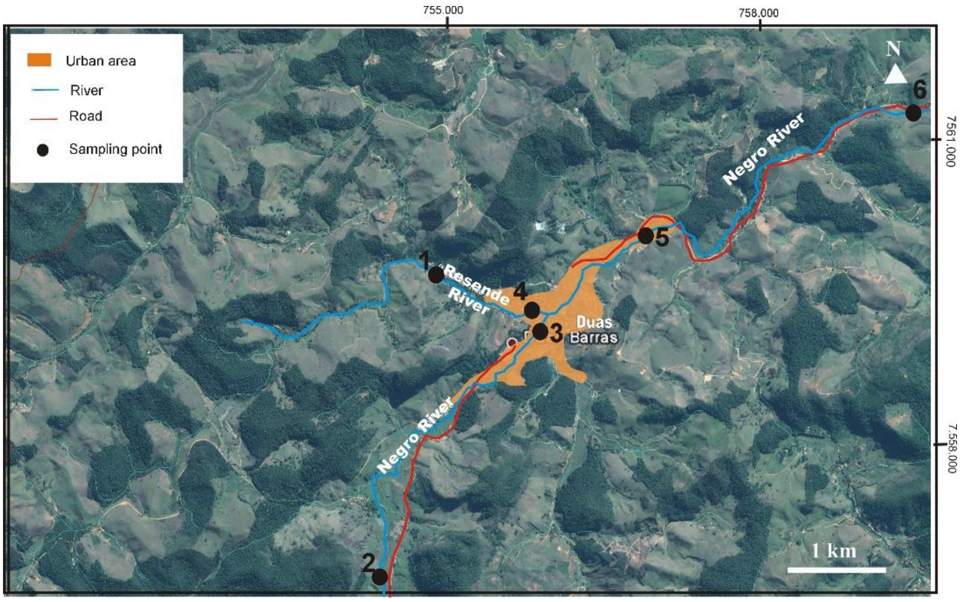

Fig. 3. Sampling points indicated on the GeoEye I orbital image (adapted from Google Earth).

Tab. 2. Parameters analyzed (modified from ANA, 2012).

Parameters	Characteristics	Anthropogenic origin
Turbidity	Degree of attenuation of intensity that a beam light suffers when crossing a certain part of water	Use of inappropriate agricultural practices; discharge of sewage and effluents
Total residue	Matter that remains after evaporation, drying or calcination of the sample at a given period of time	Fertilizers, industrial and domestic effluents
Total nitrogen	Nitrogen compounds are considered as nutrients for biological processes and can be found in water bodies in molecular form (N_2), such as ammonia (free NH_3 and ionized NH_4^+), nitrite (NO_2^-) and nitrate (NO_3^-). In water, nitrogen can be found in dissolved and suspended solids	Domestic effluents, industrial dumping, fertilizer use and animal excrement
Total phosphorus	Important nutrient for organisms present in water and limiting the growth of algae	Industrial effluents from the fertilizer, food, dairy, refrigeration and slaughtering industries
Biochemical Oxygen Demand	Amount of oxygen required for the stabilization and metabolization of the biodegradable organic material of a sample or part of water	Launch of organic loads, mainly domestic sewage
pH	Concentration of hydrogen H^+ ions, indicating conditions of acidity, alkalinity or neutrality of water	Industrial effluents or domestic waste (presence of CO_2, mineral acids and hydrolyzed salts)
Temperature	Represents the measurement of the heat intensity	Launch of industrial dumps and effluents from cooling systems, among others
Dissolved oxygen	Corresponds to the oxygen concentration dissolved in water	Industrial and domestic sewage
Thermotolerant coliforms	Important for monitoring water quality; indicates the existence of pathogenic microorganisms that may be responsible for the transmission of diseases by water contamination	Domestic sewage

The samples and data were collected at the selected points (Table 3) between 8:00 a.m. and 2:00 p.m. in March 2017. It should be noted that there was no rainfall recorded in the 24 hours prior to the procedure.

Figure 4 shows the sampling points, which were selected according to the following criteria: a) a point in each river, before the contribution of the effluents through the city and near to the springs; b) within the urbanized area, a sample in each river, before the confluence; c) one point at the exit of the urban perimeter (after the entire urban contribution); d) in the rural area, within the limits of the headquarters district.

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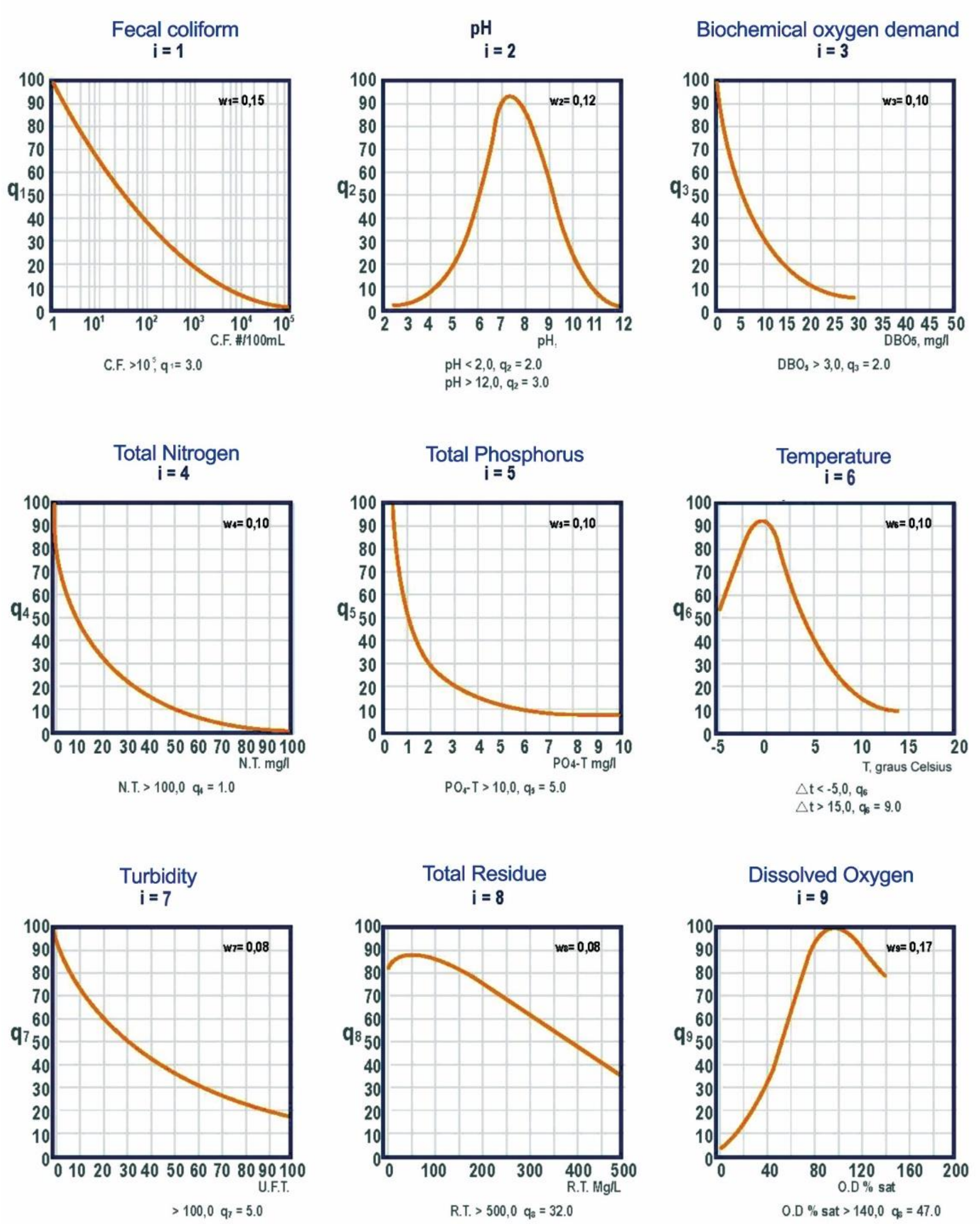

Fig. 4. Variation of water quality parameters for WQI calculation (CETESB, 2003).

Tab. 3. Water Quality Parameters of WQI and their weight. Based on ANA (2017).

Water Quality Parameters	Weight (W)
Dissolved oxygen	0.17
Thermotolerant coliforms	0.15
Hydrogen ionic potential - pH	0.12
Biochemical oxygen demand - BOD5,20	0.10
Water temperature	0.10
Total nitrogen	0.10
Total phosphorus	0.10
Turbidity	0.08
Total Insoluble Residue	0.08

Tab. 4. Classification of WQI (modified from ANA, 2017).

WQI	Interval
Very good	91 – 100
Good	71 – 90
Acceptable	51 – 70
Bad	26 – 50
Very bad	0 – 25

Altogether 36 bottles were used to collect water samples; six at each sampling point were prepared for analyses of thermotolerant coliforms, biochemical oxygen demand - BOD5,20, total nitrogen, total phosphorus, turbidity and Total Residue. The parameters temperature, dissolved oxygen and pH were measured *in situ*.

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The containers used for tests of the presence or absence of thermotolerant coliforms contained 10% sodium thiosulphate ($Na_2S_2O_3$). This procedure is performed to make inactive, if the sample contains, free residual chlorine. In this way the viability of a possible population of these bacteria can be maintained, for laboratory analysis to trace the presence of these organisms in the water.

The techniques employed and the water analysis followed the methodology suggested in the Standard Methods for the Examination of Water and Wastewater (Baird and Clesceri, 2012) contained in the National Guide for the Collection and Preservation of Samples of the National Water Agency (ANA, 2012).

4. Results and Discussion

4.1 Water Quality Index - WQI

The values of the nine parameters (Table 2) obtained in the analyzes of the samples at the six sampling points along the Negro and Resende rivers were used to calculate the WQI (Table 4). In the points with the highest occurrence of thermotolerant coliforms (Points 3, 4 and 5), the WQI was classified as bad, whereas in points 1, 2 and 6, values lower than those established by CONAMA 357/2005 for freshwater, classes 2 and 3, the indices presented acceptable values.

The results and the water classification in the six points, according to the WQI calculation are presented in Tables 5 and 6 and Fig. 5.

Tab. 5. Values obtained in each parameter and the WQI.

Sampling Points		Pt 1	Pt 2	Pt 3	Pt 4	Pt 5	Pt 6
Parameters	Units	qi^wi	qi^wi	qi^wi	qi^wi	qi^wi	qi^wi
Thermotolerant Coliform	NMP/100mL	2.00	1.99	1.26	1.26	1.23	1.60
pH		1.72	1.70	1.72	1.71	1.72	1.72
BOD	mg/L	1.55	1.50	1.50	1.51	1.51	1.58
Total Nitrogen	mg/L	1.54	1.52	1.56	1.52	1.52	1.51
Total phosphorus	mg/L	1.57	1.58	1.55	1.58	1.58	1.57
Temperature	°C	1.25	1.25	1.25	1.25	1.25	1.25
Turbidity	UNT	1.38	1.42	1.34	1.38	1.36	1.35
Total Residue	mg/L	1.43	1.43	1.42	1.43	1.43	1.42
Dissolved oxygen	% Saturation	2.16	2.18	2.15	2.17	2.15	2.13
	WQI	**68**	**67**	**40**	**42**	**40**	**52**

Tab. 6. Values of the classification of Water Quality Index.

Collect point	Result	Water quality
Point 1	68	Acceptable
Point 2	67	Acceptable
Point 3	40	Bad
Point 4	42	Bad
Point 5	40	Bad
Point 6	52	Acceptable

Figure 6 shows the distribution of the Water Quality Index according to the analyzed points and the calculation of the WQI, on the image of GeoEye I Satellite.

4.2 Thermotolerant coliforms

The presence of thermotolerant coliforms is not observed at the point near the Rio Negro spring (Figs. 7 and 8); near the Resende river spring, the results expressed values below the maximum permitted for fresh waters (classes 2 and 3, according to CONAMA Standard 357/2005). These results show that, in relation to this parameter, the waters of the springs or that found close to both springs are in accordance with the required standard quality.

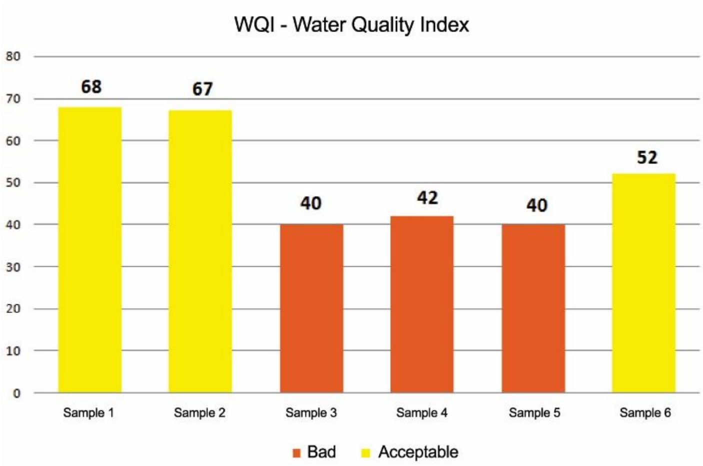

Fig. 5. Classification of the water quality of the Negro and Resende rivers.

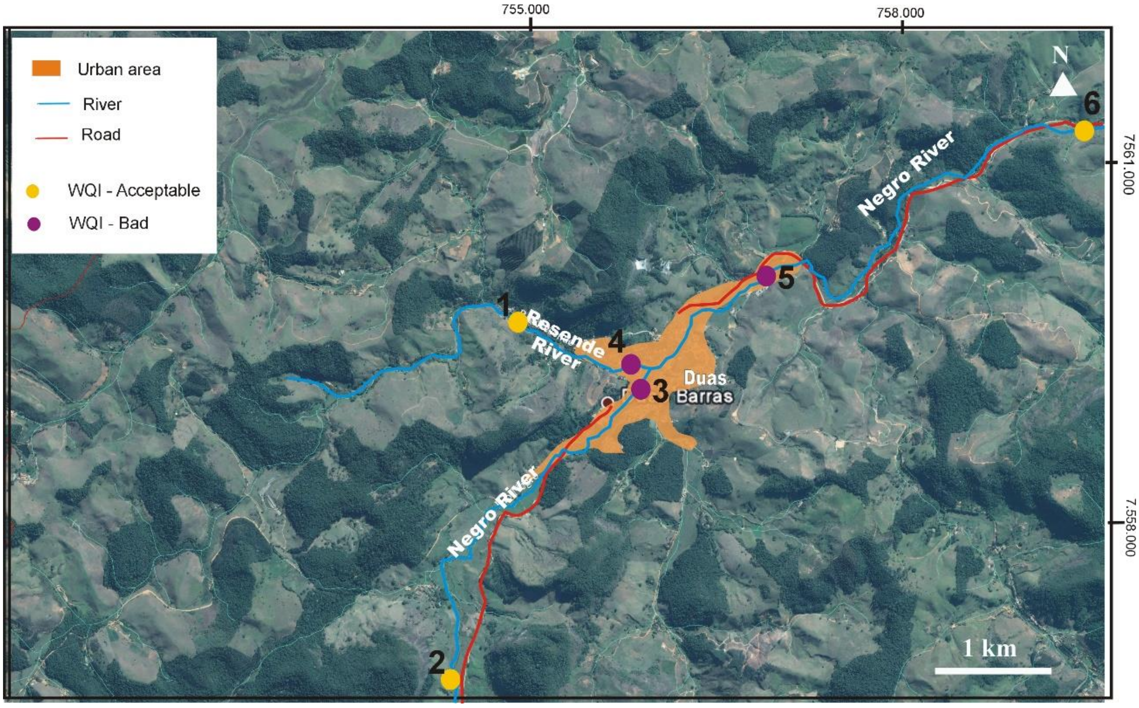

Fig. 6. Distribution of the sampling points according to the WQI classification (adapted from Google Earth).

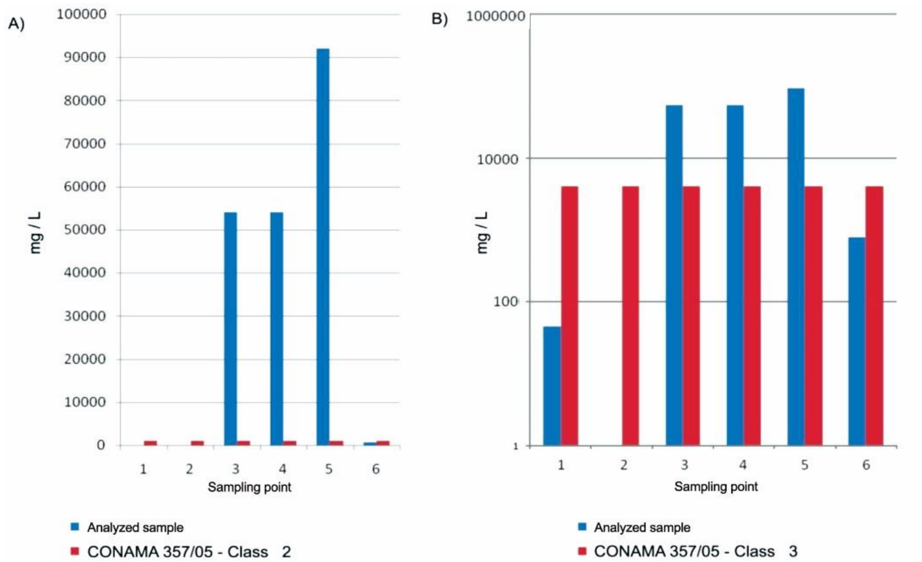

Fig. 7. Values of thermotolerant coliforms obtained at the sampling points. (A) Comparison with the limits established by CONAMA 357/2005 for class 2; (B) Comparison with the limits established by CONAMA 357/2005 for class 3.

The values resulting from the analysis of the rivers within the urban area of the municipality of Duas Barras, specifically in Points 3, 4 and 5, are 14 times higher than the maximum limit established by CONAMA 357/2005 for class 3 fresh water and 54 times higher than the limit for class 2, showing a clear contribution of the domestic sewage launch directly in the water segments. After the urban area (Point 6) there is a significant decrease in the concentrations of thermotolerant coliforms. This reduction may be caused by the existence of a tributary, which may contribute for the dilution of the coliforms.

4.3 BOD, pH, total phosphorus, Dissolved oxygen, Turbidity

In relation to the pH, total phosphorus, dissolved oxygen and turbidity parameters, the comparison of the obtained results with those of the current legislation, demonstrated levels below the maximum limit established by CONAMA Resolution 357/2005. The high river runoff discharge and the rainy season may have contributed to obtain values below the maximum permitted by CONAMA regulation.

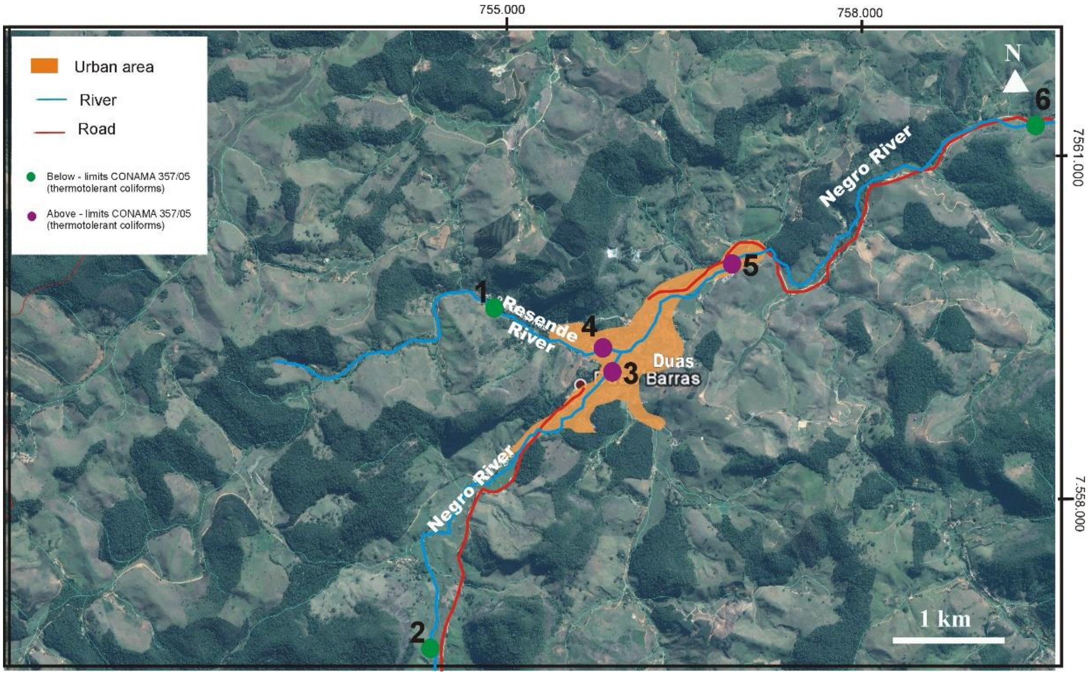

Fig. 8. Distribution of the analyzed points according to the values of thermotolerant coliforms confronted with the limits established by CONAMA 357/2005, for classes 2 and 3, on GeoEye I satellite image (Adapted from Google Earth).

According to the limits established by CONAMA 357/2005 for class 2, the results of the parameter BOD (Fig. 9) presented acceptable values in points 2, 3, 4 and 5 and a maximum value in point 5, which corresponds also to the highest value of thermotolerant coliforms.

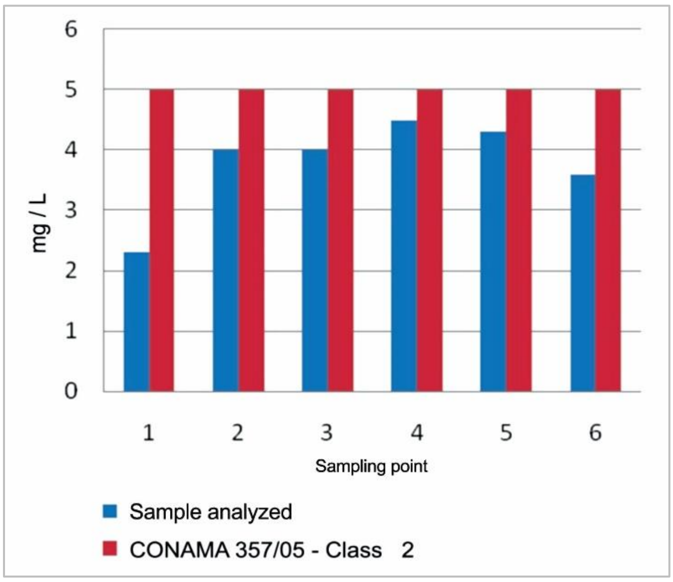

Fig. 9. BOD values at sampling points compared to the limits established by CONAMA 357/2005 for class 2.

Although the number of tested points was insufficient to obtain a more consistent level of confidence, the results of the analyzes contributed to identify the presence of organic contamination in the waters of Negro and Resende rivers due to the discharge of municipal effluents. The implementation of sewage treatment plants in the municipality, ideally reaching the tertiary phase of treatment may resolve or reduce the degree of contamination of the rivers. Where it is not possible to set up such systems, the adoption of biodigestors systems may be chosen as a mitigating measure, especially in areas with a high concentration of people, such as schools, hospitals and inns. In other areas, septic tank systems, efficiently powered by biotechnologies, should be built. Such alternatives present a low cost of implantation and maintenance in relation to conventional treatment plants.

5. Conclusion

The results of this work show the relationship between urbanization that occurs without the inclusion of effluent treatment systems and water quality. They also show that WQI is a useful tool to evaluate the interference of urbanization in the quality of water resources. The analysis of the samples demonstrated the considerable presence of organic load in the Negro and Resende rivers, with emphasis on high levels of thermotolerant coliforms. The obtained results allow to classify the water quality between acceptable and bad.

In all points located within the urban area, the WQI was classified as bad and, when compared to the resolution CONAMA 357/2005 (freshwater classes 2 and 3) for thermotolerant coliforms, presented values above those permissible. Therefore, this study shows that the absence of waste treatment in the urban area and the launching of liquid effluents with the presence of organic load in high quantities have as a consequence the contamination of the water courses used in the urban supply itself. For this reason, it is necessary to implement wastewater treatment systems, reaching at least the tertiary phase of treatment, biodigester systems, septic tanks associated to biotechnologies, in order to recover the water quality of the studied rivers.

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References

ANA, 2017. Indicadores de Qualidade – Índice de Qualidade das Águas (IQA). Available in: *http://portalpnqa.ana.gov.br/indicadores-indice-aguas.aspx*. Accessed on April 18, 2017.

ANA, 2012. Panorama da qualidade das águas superficiais do Brasil 2012. 1ª edição. Brasília/DF, Brasil. Agência Nacional das Águas, 2012.

Baird, R.B., Clesceri, A.D., 2012. Standard methods for the examination of water and wastewater 22/E.

Brown, P., Bhushan, B., 2016. Bioinspired materials for water supply and management: water collection, water purification and separation of water from oil. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 374. DOI: 10.1098/rsta.2016.0135.

Brown, R.M., Mclelland, N.J., Deininger, R.A., Tozer, R.G., 1970. A Water Quality Index - Do We Dare? Water and Sewage Works October, pp. 339-343.

Calderano, B., Polivanov, H., Guerra, A.J.T., Barroso, E.V., Chagas, C.S., Calderano, S.B., Carvalho, J.W., Donagemma, G.K., 2012. Estudo Geoambiental do Médio Alto Curso do Rio Grande (RJ), EMBRAPA Solos.

Calderano, B.F., Polivanov, H., Guerra, A.J.T., Chagas, C.S., Carvalho, W.J., Calderano, S.B., 2010. Estudo Geoambiental do Município de Bom Jardim – RJ, com Suporte de Geotecnologias: Subsídios ao Planejamento de Paisagens Rurais Montanhosas - Sociedade and Natureza, Uberlândia, 22(1), 55-73, abr.

CEPERJ (Centro Estadual de Estatísticas Pesquisas e Formação de Servidores Públicos do Rio de Janeiro), 2014. Mapa do Estado do Rio de Janeiro, Regiões de Governo e Municípios.

CETESB, 2003. Companhia de Tecnologia de Saneamento Ambiental. Relatório de qualidade das águas interiores do Estado de São Paulo 2002. São Paulo: Cetesb, 2003 (Série Relatórios).

Clima Date. Tabela Climatica de Duas Barras. Available in: *https://pt.climate-data.org/location/316580/*. Access on August 19, 2017.

CONAMA. Resolução CONAMA. nº 357 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. publicada no DOU nº 053 de 18/03/2005.

Heilbron, M., Pedrosa-Soares, A.C., Campos Neto, M., Silva, L.C., Trouw R.AJ., Janasi, V.C., 2004. Brasiliano Belts in SE Brazil. Journal of Virtual Explorer, 17.

Helmer, R., Hespanhol, I. 1997. Water pollution control: a guide to the use of water quality management principles / edited by Richard Helmer and Ivanildo Hespanhol. London: E and FN Spon. Available in: *http://www.who.int/iris/handle/10665/41967*

Horton, R.K., 1965. An index-number system for rating water quality. Journal of Water Pollution Control Federation 37 (3), 300-306.

IBGE, Instituto Brasileiro de Geografia e Estatística. Panorama. Available in: https://cidades.ibge.gov.br/brasil/rj/duas-barras/panorama. Accessed on: 15 Apr 2018.

Köppen, W., Geiger, R., 2007. Klimate der Erde. Gotha: Verlag Justus Perthes. 1928.

NSF, 2007. National Sanitation Foundation Consumer Information: Water Quality Index. Ann Arbor/MI, United States of America.

Santin, J.R., Corte, T.D., 2011. Planejamento urbano e princípio da prevenção na gestão dos recursos hídricos. Revista do Programa de Pós-Graduação em Direito da UFC. Rio Grande do Sul, Brazil.

SNIS - Sistema Nacional de Informações Sobre Saneamento. Coleta de Dados - Água e Esgotos. Available in: *<http://www.snis.gov.br/coleta-de-dados-snis-agua-e-esgotos> Accessed on September 2, 2017.*

Tupinambá, M., 2012. Geologia e Recursos Minerais da Folha Nova Friburgo (CPRM/UERJ) Escala 1:100.000 Estado do Rio de Janeiro.

Weinberg, A., 2013. Uso de índices de qualidade de água para a caracterização da bacia hidrográfica do rio Guandu. Ágatha Weinberg - Rio de Janeiro. UFRJ/ Escola Politécnica.