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FAVORABLE IMPACTS OF A FRAGMENT OF ATLANTIC FOREST ON WATER QUALITY IN AN URBAN RIVER IN NORTHEASTERN BRAZIL

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Abstract. The Jaguaribe river is entirely urban in its extent. It follows a convoluted course through the city of João Pessoa, the capital of the State of Paraíba. As with other urban water bodies in Brazil, the quality of its water is compromised by diffuse contaminations arising from a diverse array of polluting sources originating from diverse localities along its course. On the basis of hydric monitoring, accomplished by the "Superintendência de Administração do Meio Ambiente" (SUDEMA), it was possible to infer that water quality is best in the stretch contained within the area of environmental preservation "Mata do Buraquinho", today named Botanic Garden 'Benjamin Maranhão'. This ecosystem, located in the central region of João Pessoa, provides several environmental services to the population living in this city, such as climatic regulation, genetic resources, biodiversity, recreation, and ecotourism, among others. It also produces positive impacts on the water quality of the river flowing through this preservation area. Data from chemical analyses were listed as temporal series (2006 to 2016), making it possible to compare two water sampling stations (JB01 e JB02). Alterations were recorded for some parameters, such as water color, turbidity, number of heat-toletant coliforms, and increase in dissolved water oxygen.

Keywords: Phytomedication; Environmental monitoring; Water chemistry.

IMPACTOS POSITIVOS DE UM FRAGMENTO DE MATA ATLÂNTICA NA QUALIDADE DA ÁGUA DE UM RIO URBANO NO NORDESTE BRASILEIRO

Resumo. O Rio Jaguaribe é um rio inteiramente urbano, presente exclusivamente na cidade de João Pessoa. Como de regra no Brasil, ele não se diferencia da realidade de outros corpos hídricos urbanos, ou seja, tem sua qualidade comprometida pelas contaminações difusas provenientes das mais diversas

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fontes poluidoras da própria cidade. Através de ferramentas como o monitoramento hídrico, que é realizado pela Superintendência de Administração do Meio Ambiente (SUDEMA) foi possível constatar a melhora da qualidade do rio, no trecho no qual ele atravessa a área de preservação ambiental Mata do Buraquinho, hoje Jardim Botânico Benjamin Maranhão. Esse ecossistema situado na região central de João Pessoa disponibiliza inúmeros serviços ambientais aos moradores da capital paraibana, como a regulação climática, os recursos genéticos e a biodiversidade, recreação e ecoturismo entre outros, além de trazer impactos positivos no corpo hídrico que o tem como rota. Os dados de análises químicas foram elencados em séries temporais (2006 a 2016), comparando duas estações de amostragem de água (JB01 e JB02), onde houve algumas alterações de parâmetros como: redução dos níveis de cor, turbidez, do número de coliformes termotolerantes e aumento do oxigênio dissolvido na água.
Palavras-chave: Fitorremediação; Monitoramento ambiental; Química da água.

IMPACTOS POSITIVOS DE UN FRAGMENTO DE 'MATA ATLÁNTICA' EN LA CALIDAD DEL AGUA DE UN RIO URBANO EN EL NORDESTE BRASILEÑO

El Río Jaguaribe es un río totalmente urbano, presente exclusivamente en la ciudad de João Pessoa. Siendo la regla en Brasil, no es diferente de la realidad de otros cuerpos hídricos urbanos, o sea, tiene su cualidad comprometida por la contaminación difusa proveniente de las más diversas fuentes contaminantes de la propia ciudad. A través de herramientas como el monitoreo hídrico, que es realizado por la "Superintendência de Administração do Meio Ambiente" (SUDEMA) fue posible constatar que la mejoría de la cualidad del rio, en el trecho donde atraviesa el área de preservación ambiental "Mata del Buraquinho", hoy Jardín Botánico 'Benjamín Maranhão'. Ese ecosistema localizado en la región central de João Pessoa suministra diversos servicios ambientales a los moradores de la capital paraibana, como regulación climática, recursos genéticos y biodiversidad, recreación y ecoturismo, entre otros; además de traer impactos positivos en el cuerpo hídrico que lo tiene como ruta. Los datos de análisis químicas fueron clasificados en series temporales (2006 a 2016), comparando dos estaciones de muestras de agua (JB01 y JB02), donde hubo algunas alteraciones de parámetros como: reducción de los niveles de color, turbiedad, del número de coliformes termotolerantes y aumento del oxígeno disuelto en el agua.
Palabras clave: Fitorremediación; Monitoreo ambiental; Química del agua.

INTRODUCTION

Concerns with water quality has been increasing worldwide. The problem of limited water resources has been much discussed and will represent one of the major challenges of the present century. Water is fundamental for the development of any country. Even tough, as a result of several factors, this precious liquid is becoming more and more insufficient. Water is being consumed in a disorganized way, reducing even further the availability of drinking water in our planet (MC EGAN, 2013).

Contamination produced by urban effluents, such as domestic sewage and industrial discharges are the main sources of pollution of our urban water bodies. Our urban rivers thus become degraded, without much perspective of revival actions on the part of our public institutions (TUCCI, 2001).

The Jaguaribe River is the largest urban river within the city of João Pessoa. Its nascent is located in the Esplanada neighborhood, in the southern section of the city. Presently, this fountain area is grounded. The river flows for 21 km before draining into the Atlantic Ocean. It crosses through several neighborhoods of the city of João Pessoa, including the forest reserve of "Buraquinho" (presently named Botanical Garden Benjamim Maranhão). Originally, it drained into the sea in the proximity of the Bessa Beach and Campina Point. However, due to an intervention in the original riverbed, it has been redirected to the Mandacaru River. Both rivers now have become tributaries of the Paraíba River (MELO, 2000).

With the institution of the Federal Law n°9.433, of 1997, which has become known as the "Law of the Waters", a national policy for Water Resources has been implemented. Among its instruments is found a framework for the classification of all water resources, and for their public use and management, the National Policy of Water Resources. The system for the classification of water bodies was updated in 2005, by a Resolution from the National Environmental Council (Resolução do Conselho Nacional do Meio Ambiente - CONAMA nº 357/05) (BRASIL, 2005).

The Superintendency for Environmental Administration ("Superintendência de Administração do Meio Ambiente") (SUDEMA) surveys most bodies of water in the State of Paraíba. This Public Agency samples these water bodies in intervals that vary from one to three months, for the monitoring of the water quality of these hydric resources. The Executive State Water Agency (Agência Executiva de Águas da Paraíba) (AESA) is responsible for inspecting and licensing the use of the hydric resources of the State. SUDEMA conducts the qualitative survey in the form of environmental monitoring, with the aim of detecting possible changes in water quality and of identifying the possible causes of this type of impact (SUDEMA, 2016).

The aim of this paper is to identify the positive impacts on water quality caused by the flowing of the Jaguaribe River through the Botanical Garden Benjamin Maranhão. Physical, chemical and microbiological data provided by SUDEMA were analyzed with this objective in mind.

MATERIAL AND METHODS

Study area

The study area is located in the Municipality of João Pessoa, which is inserted into the Atlantic Forest microregion (IBGE, 2010). The Jaguaribe River is born near the Conjunto Esplanada, located in the southern sector of the city, and drains into the larger Paraíba River (Fig. 1). According to the classification of W. KÖPPEN, the climate is of the As` type, characterized as warm and humid, with rains during autumn and winter. The mean annual temperature is 23º C, with a maximum of 28º C, and a thermal amplitude of 5º C (MELO, 2000).

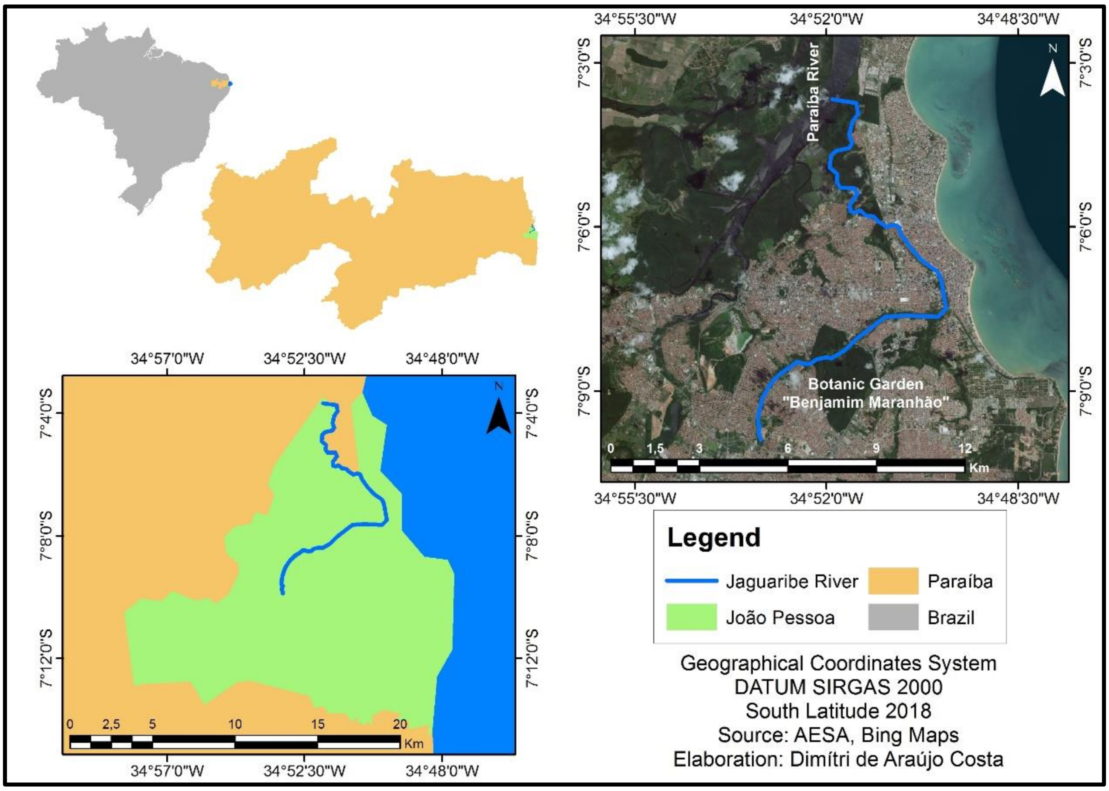

Figure 1. Map showing the location of the Jaguaribe River, Municipality of João Pessoa, State of Paraíba, Northeastern Brazil.

The Botanical Garden Benjamin Maranhão contains a representative section of the Atlantic Forest of the State of Paraíba. Its forest fragment measures 519.75 ha, being located in the urban area of the Municipality of João Pessoa, littoral region of the State of Paraíba. It is located within the Geological formation of the Lower Coastal Plain. The forest is semi deciduous, covering planes of low altitude (IBGE, 2010).

According to Carvalho et al. (2001), this environmental reserve represents the largest area of native urban forest in the country. Its phytological composition is characterized as a floristic complex, including elements of the Amazon Forest and of the Hileia typical of the State of Bahia, as well as elements of the Atlantic Forest (BARBOSA, 1996).

Location and description of sampling sites

Sampling is an important component in environmental monitoring. In order for the collected material to adequately represent a chosen area of study, it is necessary to follow some protocols and techniques that vary according to the paramenters that we are interested in, as depend on the type of material collected. The sampling spots must be selected carefully and the techniques must be chosen judiciously for conservation studies.

In this work, information was used from two sampling stations on the Jaguaribe River (Fig. 2): JB01, located in the Jaguaribe neighborhood, which is upstream from the Botanical Garden; and JB02, located on Pedro II avenue, located downstream and adjacent to the Botanical Garden. Although SUDEMA samples other stations in its monitoring program, these two stations are most significant for demonstrating the effects that the preservation area represented by the Botanical Garden has on the water quality of the river.

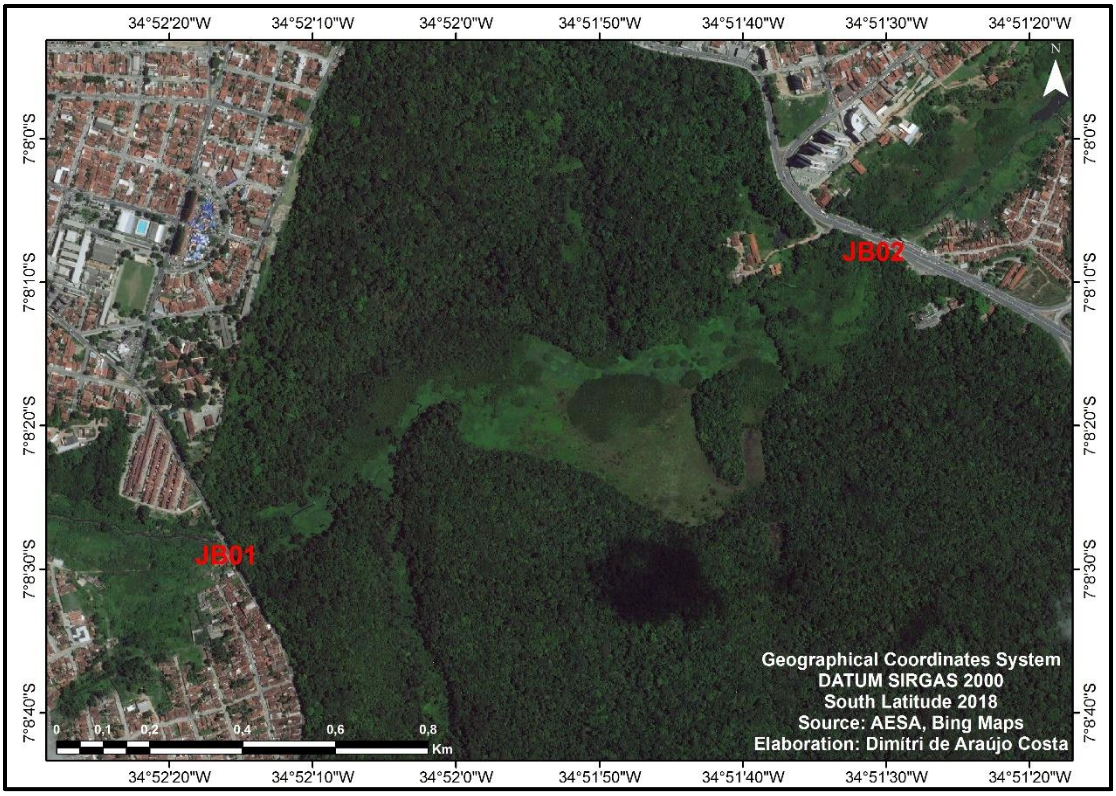

Figure 2. Sampling stations on Jaguaribe River (JB01 and JB02), located on either side of the Botanical Garden Benjamin Maranhão.

Methods and Techniques

Sampling was done four times a year during the years from 2006 to 2016, following protocols contained in the National Guide for the collecting and preservation of samples (GUIA NACIONAL DE COLETA E PRESERVAÇÃO DE AMOSTRAS) (ANA e CETESB, 2011).

Samples were obtained with poliethylene frascs placed in the central course of the river. The parameters of dissolved oxygen, temperature and PH were measured in the field, with the multiparmetric probe HACH 40Q. This probe was calibrated previously to the measurements in each collecting station. The microbiological samples (heat-tolerant coliforms) were collected in temperatures of approximately 4°C, as recommended in the guide. These samples were then transported to the Laboratory of Environmental Measurements ("Laboratório de Medições Ambientais"), belonging to SUDEMA, and analyzed with the technique of filtering membranes.

The remaining parameters (water color, turbidity, electric conductivity) were analyzed in the lab based on *Standard Methods for the Examination of Water and Wastewater* (APHA, 2012).

Univariate statistical analyses were conducted in the statistical program PAST version 3.13. Values equal or smaller than 5% (≤0,05) were considered statistically significant (HAMMER et al., 2001).

RESULTS

Data were selected from the historical database obtained for the Jaguaribe River during the years from 2006 to 2016. The results are displayed in Tab. 1 and Figs. 3 to 7.

Table 1. Mean annual values for the environmental variables at stations JB01 (upstream) and JB02 (downstream) for the Jaguaribe River, during the years 2006 to 2016 (source: CMA/SUDEMA). Legend: C.E. (Electric conductivity); O.D. (Dissolved oxygen); H.C. (heat-tolerant coliforms).

Year	**Color**		**Turbidity**		**E.C.**		**D.O.**		**H.C.**	
	JB01	JB02	JB01	JB02	JB01	JB02	JB01	JB02	JB01	JB02
2006	41,00	37,00	9,00	8,00	346,00	297,00	1,56	1,52	42666,67	12416,67
2007	63,00	51,00	27,00	14,00	341,00	301,00	1,73	1,69	323833,33	33250,00
2008	59,00	33,00	32,00	10,00	324,42	285,50	2,27	2,60	54083,33	19833,33
2009	35,00	24,00	12,00	5,00	339,33	288,58	2,21	3,29	69625,00	8000,00
2010	51,00	35,00	12,00	5,00	392,33	317,58	1,54	2,61	62363,64	11727,27
2011	44,00	29,00	46,00	50,00	314,11	290,89	2,00	3,20	144466,67	29033,33
2012	61,00	43,00	45,00	20,00	229,25	257,00	3,50	4,50	35700,00	21500,00

2013	76,00	75,00	12,00	6,00	336,75	306,25	1,70	3,20	4717,00	1715,25
2014	41,00	38,00	15,00	5,00	338,50	314,75	1,70	3,20	72100,00	14133,33
2015	51,00	42,00	12,00	6,00	403,33	370,67	1,80	3,60	343433,33	127266,67
2016	66,90	67,94	20,57	32,04	412,80	390,00	0,55	0,83	883040,00	592580,00

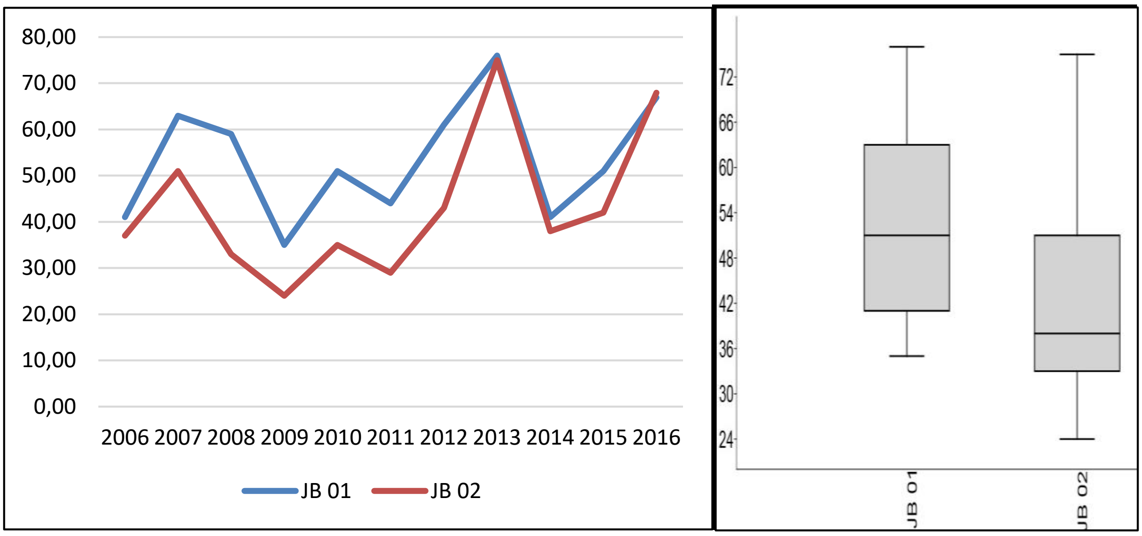

Figure 3. Line graphic and Box Plot for the variable "Color", during the years 2006 to 2016.

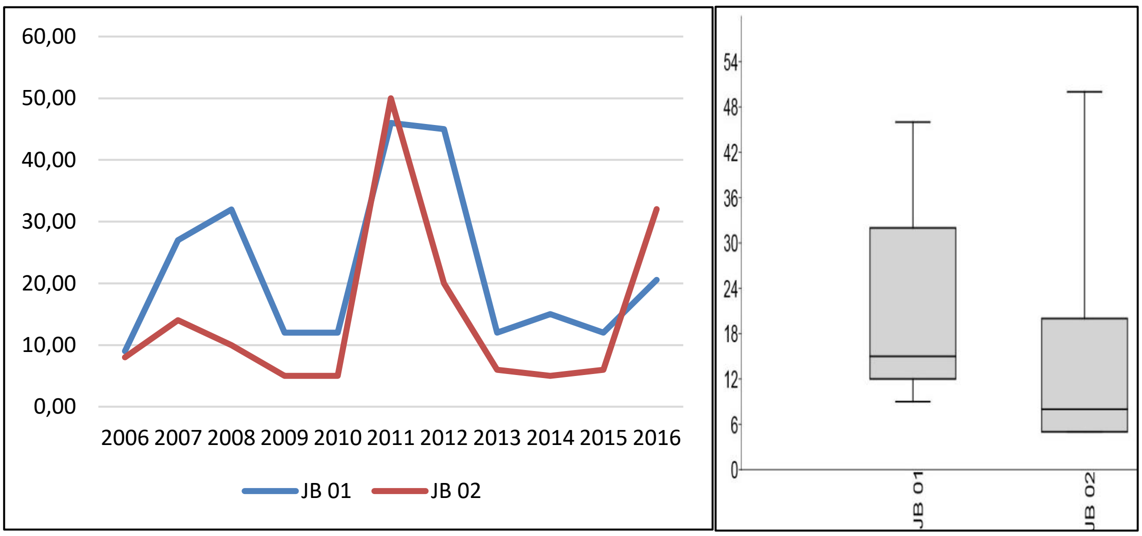

Figure 4. Line graphic and Box Plot for the variable "Turbidity", during the years 2006 to 2016.

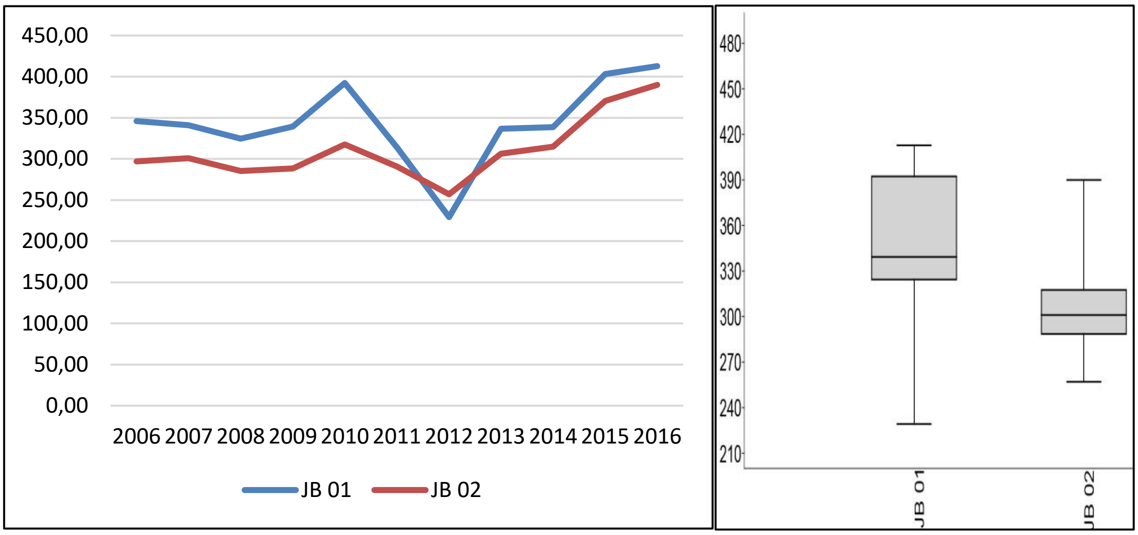

Figure 5. Line graphic and Box Plot for the variable "Electrical Conductivity", during the years 2006 to 2016.

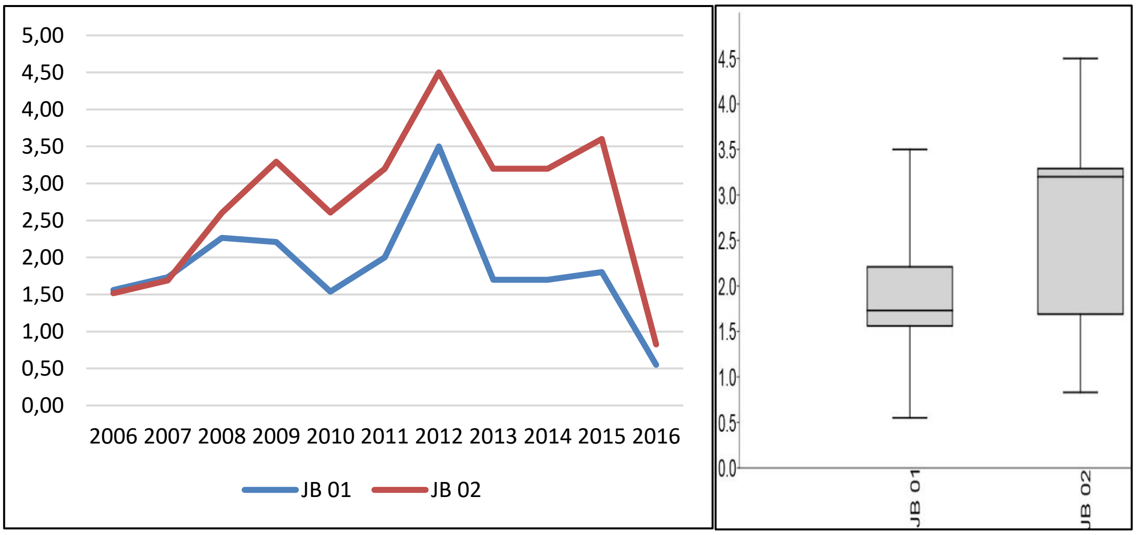

Figure 6. Line graphic and Box Plot for the variable "Dissolved Oxygen", during the years 2006 to 2016.

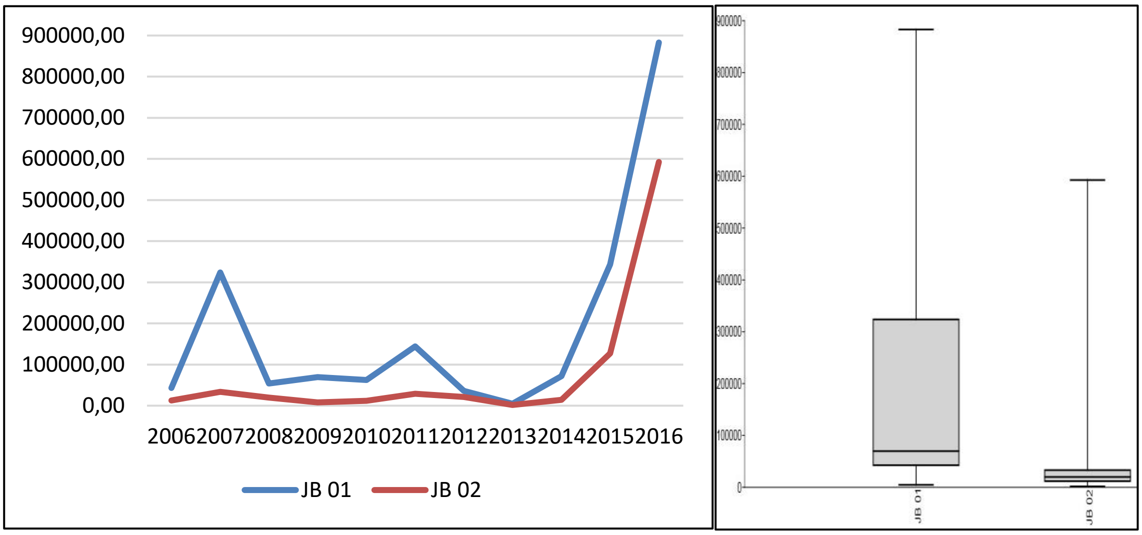

Figure 7. Line graphic and Box Plot for the variable "Heat-tolerant Coliforms", during the years 2006 to 2016.

According to table 1 and figures 3 to 7, station JB02 presented more favorable results for all the used indicators during the years 2006 to 2016. The means for water color (from 53,54±12,73 to 43,18±15,79), turbidity (from 22,05±13,60 to 14,64±14,41), electrical conductivity (from 343,44±50,15 to 310,84±38,28) and heat-tolerant coliforms (from 185093,50±258179,50 to 79223,26±173686,70) all diminished along the water course. Furthermore, the levels of dissolved oxygen increased (from 1,87±0,71 to 2,75±1,05) from the first to the second station (tables 1 and 2, figures 1, 2, 3, 4 and 5).

Statistical tests were conducted to confirm the improvement of the environmental variables (Tab. 2).

Table 2. Results of the statistical tests conducted for the environmental variables in stations JB01 and JB02 in the Jaguaribe River, during the years 2006 to 2016.

	Color	Turbidity	E.C.	D.O.	H.C.
Shapiro-Wilk	0,94	0,80	0,91	0,95	0,66
p value	0,19	4,92 x 10^{-4}	0,04	0,32	6,57 x 10^{-6}
T test	4,19			-4,52	
p value	1,87 x 10^{-3}			1,10 x 10^{-3}	
Wilcoxon test		56	62		66
p value		0,04	9,93 x 10^{-3}		3,35 x 10^{-3}

The values calculated in table 2 indicate that the variables Color and O.D. presented a normal distribution (i.e., they are parametric), because the values for “p” in the normality test of Shapiro-Wilk were not significant (0,19 to 0,32, respectively). The test T was calculated in order to compare the difference between the stations located upstream and downstream. We verified that the two indicators had significant values ($1,87x10^{-3}$ and $1,10x10^{-3}$, respectively). This corroborates the hypothesis of improvement of these indicators along the studied river course (Tab. 2).

On the other hand, the variables turbidity, C.E. and H.C. did not present a normal distribution (i.e., they are non-parametric), having significant values for “p(normal)” ($4,92x10^{-4}$; 0,04 and $6,57x10^{-6}$, respectively). Thus, the non-parametric test of Wilcoxon was applied, and it was verified that all values of “p” were significant (0,04; $9,93x10^{-3}$ and $3,35x10^{-3}$, respectively). These results also confirm that these variables improved at the second station (Tab. 2).

DISCUSSION

Phytomedication can be presented as one of the most plausible explanations for the results obtained. During the river course within the forested reserve, no additional source of pollution are found. At this interaction zone, along the course of the river within the forest, may be occurring the bioremediation process, as presented by Manahan (2000). All factors involved contribute to the observed result of water quality improvement observed in station JB02.

Phytomedication with aquatic macrophytes is a natural process that occurs in several water courses. The macrophytes function as bioindicator species for the presence of pollutants (PALMA-SILVA et al., 2012; SANTOS, 2017). These macrophytes are bioaccululators of chemical pollutants, and absorb great quantities of nutrients (PALMA-SILVA et al., 2012; SANTOS, 2017).

CONCLUSIONS

In conclusion, the Botanical Garden Benjamin Maranhão exerts favorable impacts on the water quality of the Jaguaribe River, particularly regarding the parameters analyzed and presented herein. The forested area helps the river to purify itself of a significant portion of its contaminants.

This study indicates that when sources of river pollution are eliminated, it is possible to reach improvements in the water quality of the river. On the other hand, other types of intervention, such as the removal of silt, for example, are of no use for regaining water quality, when the sources that contribute to water degradation are not eliminated.

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