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ARTICLES

The historical influence of tributaries on the water and sediment of Jacuí's Delta, Southern Brazil

A influência histórica dos afluentes na água e sedimento do Delta do Jacuí, RS, Brasil

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Abstract: The high population density in a metropolis leads to socio-environmental impacts that directly affect local water resources. This work evaluated the historical data (between 2000 and 2014) of water and sediment monitoring in the Jacuí's Delta region and analyzed the relationship between these sites. Seven monitoring sites around the Jacuí's Delta were evaluated: the outflow of the rivers Jacuí, Caí, Sinos, and Gravataí; the channels Ilha da Pintada and Navegantes; and Lake Guaíba. Water data were evaluated for: air and water temperature; depth; pH; electrical conductivity; transparency; turbidity; dissolved oxygen; biochemical oxygen demand; phosphorus; nitrogen; total residues; and escherichia coli. Sediment were evaluated for pseudo-total concentrations of metals (Al, Fe, Ca, Mn, Ba, V, Zn, Cu, Pb, Cr, Ni, Co, Li, Be, Cd, Hg, As, and Ag). The quality of water and sediment in the Jacuí's Delta are linked with the tributaries and priority flows of the channels. The historical data of water and sediment around the Jacuí's Delta shows the influence of the tributaries with low quality in the downstream points. The pollution of the rivers Caí, Sinos, and Gravataí negatively affects the environmental quality of the channel Navegantes and Lake Guaíba (catchment points to water supply). The water in those sites presents reductions in dissolved oxygen and high values of coliforms, and the sediment shows high concentrations of metal Zn, Pb, Cr, and Hg. Despite the reduction in Pb and Hg values in the sediment over the past years, pollution from the tributary rivers still persists.

Keywords: monitoring, pollution, watershed.

Resumo: A grande densidade populacional nas metrópoles gera impactos socioambientais que afetam diretamente os recursos hídricos locais. O objetivo deste trabalho foi avaliar os dados históricos (entre 2000 e 2014) de monitoramento de água e sedimentos na região Delta de Jacuí e analisar a relação entre esses locais. Foram avaliados sete locais de monitoramento entorno do Delta de Jacuí: foz dos rios Jacuí, Caí, Sinos e Gravataí; canais Ilha da Pintada e Navegantes; e Lago Guaíba. Os dados de água foram avaliados para: temperatura do ar e da água; profundidade; pH; condutividade elétrica; transparência; turbidez; oxigênio dissolvido; demanda bioquímica de oxigênio; fósforo; nitrogênio; resíduos totais; e escherichia coli. Os sedimentos foram avaliados para concentrações pseudo-totais de metais (Al, Fe, Ca, Mn, Ba, V, Zn, Cu, Pb, Cr, Ni, Co, Li, Be, Cd, Hg, As e Ag). A qualidade da água e dos sedimentos no delta de Jacuí está ligada aos afluentes e fluxos prioritários dos canais. Os dados históricos de água e sedimentos no Delta de Jacuí mostram a influência dos afluentes com baixa qualidade nos pontos a jusante. A poluição dos rios Caí, Sinos e Gravataí afeta negativamente a qualidade ambiental do canal Navegantes e do Lago Guaíba (pontos de captação para abastecimento hídrico). A água nesses locais apresenta reduções no oxigênio dissolvido e grandes valores de coliformes e o sedimento apresenta grandes concentrações dos metais Zn, Pb, Cr e Hg. Apesar da redução ao longo dos anos nos valores de Pb e Hg no sedimento, a poluição dos rios tributários ainda persiste.

Palavras-chave: bacia hidrográfica, monitoramento, poluição.

1. INTRODUCTION

The large expansion of big cities results in environmental impacts on local water resources, which often serve as a source of water for the same populations (Cavalcanti et al., 2014). Trace metals entering aquatic ecosystems through runoff or atmospheric deposition and eventually accumulate in sediments (Bing et al., 2016).

Lake Guaíba is the major source of water in the capital of the Rio Grande do Sul State. The lake has had historical, economic and cultural importance for the region since the 18th century. With almost 500 km^2 of shallow waters, Lake Guaíba is the final destination of the rivers Jacuí, Caí, dos Sinos, and Gravataí - accumulating potential liabilities generated in the drainage basin. Water pollution in Lake Guaíba's watershed has been noted since the end of 1950 (Freitas, 1962; Roessler, 2005), persisting for decades as a public perception. Nowadays, the waters have multiples uses: as water supply, sewage dilution, navigation, as well as fishing (Andrade et al., 2018).

The Jacuí's Delta (Figure 1) is an area of protection and great socio environmental interest, being the archipelago of a State Conservation Unit. This work evaluated the historical data (between 2000 and 2014) of water and sediments monitoring, developed by the Municipal Department of Water and Sewage (Dmae) of Porto Alegre in the Jacuí's Delta region. This work also analyzed the relationship between the sites.

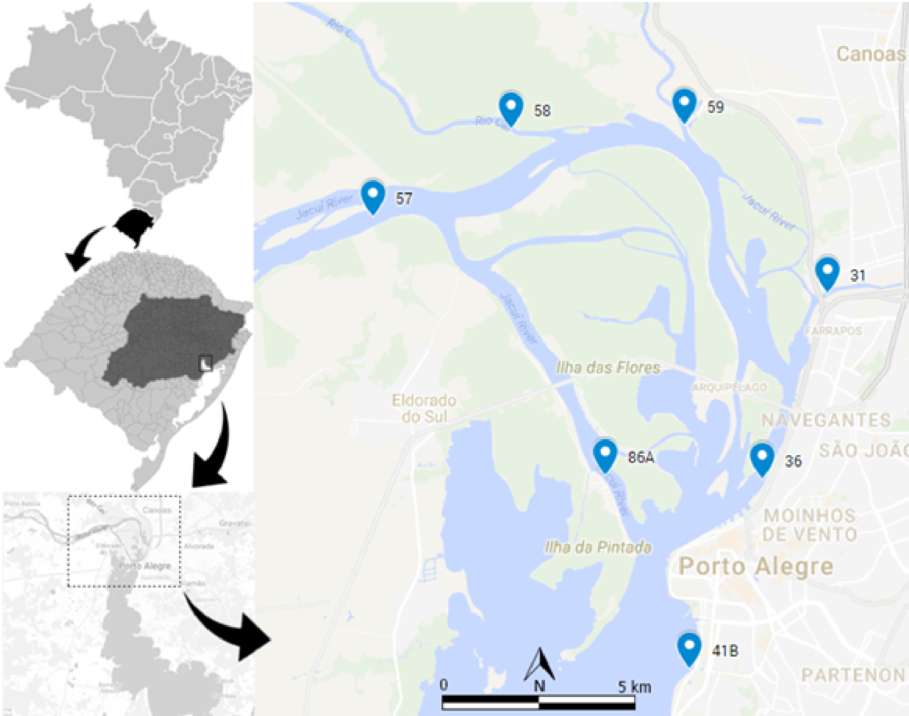

Figure 1.

Sampling sites (31 - Gravataí River; 36 - Navegantes Channel; 41B - Lake Guaíba; 57 - Jacuí River; 58 - Caí River; 59 - dos Sinos River; 86A - Ilha da Pintada Channel) of water and sediment in Jacuí's Delta. The darker area in the state map represents the lake's drainage basin.

Source: Google Maps.

2. MATERIALS AND METHODS

Analyses of water and sediment monitoring were carried out by the Municipal Department of Water and Sewage (Dmae) of Porto Alegre, RS, between 2000 and 2014. The seven sites evaluated around the Jacuí's Delta (Figure 1) were: 31 - Gravataí River outflow (29°58'12,6" S; 51°11'53,6" W); 36 - Navegantes Channel (30°00'52,1" S; 51°12'54,2" W); 41B - Lake Guaíba (30°03'32,7" S; 51°14'10,3" W); 57 - Jacuí River outflow (29°57'07,3" S; 51°19'21,2" W); 58 - Caí River outflow (29°55'51,7" S; 51°17'05,3" W); 59 - Sinos River outflow (29°55'49,0" S; 51°14'14,9" W); and 86A - Ilha da Pintada Channel (30°00'49,0" S; 51°15'34,2" W). Some of these sites are points of water catchment for Water Treatment Plants (WTP): 36 - São João and Moinhos de Ventos; 41B - Menino Deus; and 86A - Ilha da Pintada. Site numbers are standards codes defined by Dmae.

Water data, with monthly repetitions between the years 2000 and 2014, were evaluated for: air and water temperature; depth; pH; electrical conductivity (EC); transparency (secchi disk); turbidity (NTU); dissolved oxygen (DO - modified Winkler); biochemical oxygen demand (BOD_5 - manometric); total phosphorus (P - titulometric); total nitrogen (N - titulometric); total residues at 105°C (TR_{105} - gravimetric); and escherichia coli (enzymatic substrate). Sediment (bulk) was ovendried (50°C) and evaluated, with two annual repetitions in distinct seasons between the years of 2000 and 2011, to pseudo-total (USEPA, 2007) concentrations (dry basis) of metals (Al, Fe, Ca, Mn, Ba, V, Zn, Cu, Pb, Cr, Ni, Co, Li, Be, Cd, Hg, As, and Ag) and analyzed by atomic absorption spectrophotometry.

Data were submitted to analysis of variance (ANOVA) and, when significant, means were compared by Tukey test with a 95% confidence interval ($p<0.05$). All graphs and statistical analyzes were developed in Statistica® v13 software.

3. RESULTS AND DISCUSSION

The quality of water and sediment in the Jacuí's Delta are linked with the tributaries and priority flows of the channels (Figure 1). Lake Guaíba has a historical mean water inflow of 780 $m^3 s^{-1}$ (with occasional events exceeding 3000 $m^3 s^{-1}$). This inflow is composed mostly (85%) of waters from Jacuí River (point 57) and the remaining by the Rivers Sinos, Caí, and Gravataí (flowing into the Jacuí's Delta), as well as small streams along the margins (Menegat et al., 2006; Andrade Neto et al., 2012; Porto Alegre, 2017b).

The relationship of the forming rivers with the Jacuí's Delta is observed in the cluster analysis (Figure 2a), such at Points 57 (Jacuí River outflow) and 86A (the channel of the Jacuí Delta - Ilha da Pintada). However, the greatest influence of the tributaries is verified by the accumulation of liabilities of the Rivers Caí (58), Sinos (59), and Gravataí (31) over the channel Navegantes (36) and Lake Guaíba (41B). The Rivers Caí and Sinos flow through regions with many industries, especially leather and footwear; and Gravataí River flows through the metropolitan region of Porto Alegre.

The pollution from tributaries can be verified by the increase in electrical conductivity (EC), biochemical oxygen demand (BOD5), P, N, TR105, and coliforms in water (Table 1), and metals (such as Zn, Cu, Pb, Cr, Ni, and Hg) in the surface sediment (Table 2) in the downstream points (such as 36 and 41B). Consequences of these changes are reductions in pH, dissolved oxygen (DO), and water transparency - which can result in damage to local biota.

These parameters have direct and indirect connections with the urban pollution commonly present in metropolitan regions (Figure 2b). Metals and other pollutants enter the aquatic environment by various ways and sources (natural and anthropogenic), such as runoff, sewage, atmospheric deposition, and vehicular traffic (Smol, 2008; Bing et al., 2016). High vehicular traffic has been reported around the world as a potential source of pollution by metals (Zhang et al., 2016; Sharley et al., 2016). Motor vehicles have a variety of emissions and releases involving many toxic metals (such as Zn, Cr, Cu, Hg, Ni, and Pb), which damage human health and the environment (Adamiec et al., 2016).

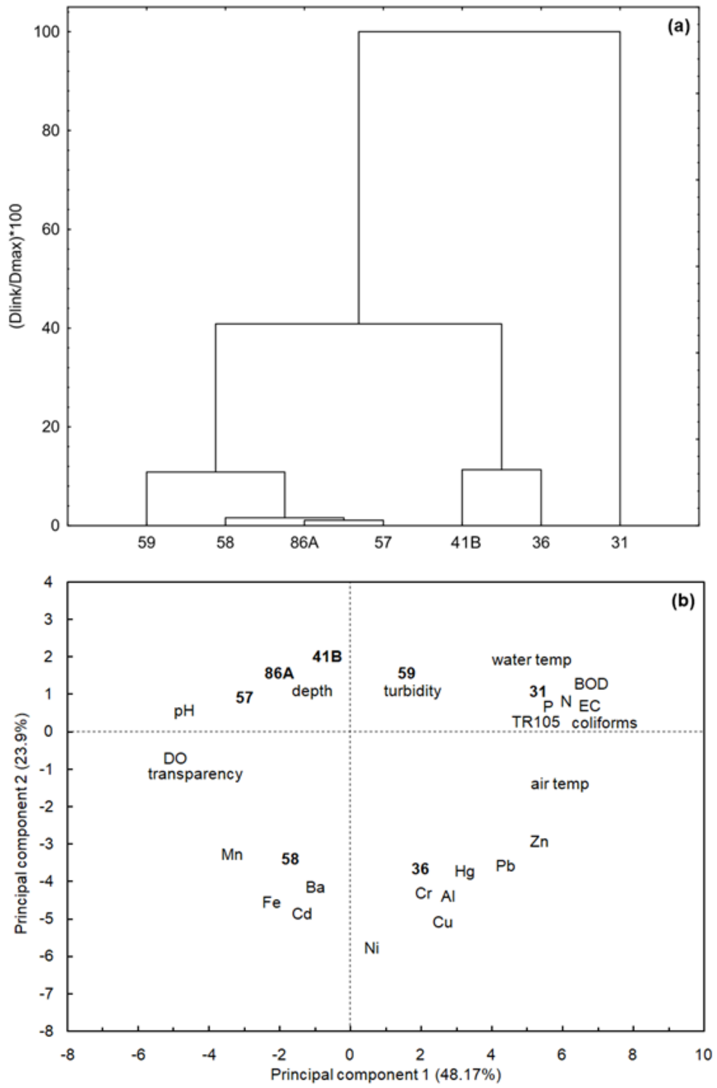

Figure 2.
Analysis of (a) clusters for the sites and (b) principal components for water and sediment in Jacuí's Delta.

Table 1.
Historical means (2000 to 2014) of water parameters around the Jacuí's Delta.

Parameters	31 Gravataí River	36 Navegantes	41B Lake Guaíba	57 Jacuí River	58 Caí River	59 Sinos River	86A Ilha da Pintada
air temperature (°C)	22.0±0.4 ^{a}	21.8±0.4 ^{a}	21.0±0.4 ^{a}	21.0±0.4 ^{a}	21.2±0.4 ^{a}	21.5±0.4 ^{a}	21.5±0.4 ^{a}
water temperature (°C)	21.6±0.4 ^{a}	21.2±0.4 ^{a}	21.2±0.4 ^{a}	21.1±0.4 ^{a}	20.8±0.4 ^{a}	20.9±0.4 ^{a}	21.1±0.4 ^{a}
depth (m)	4.5±0.1 ^{cd}	6.6±0.0 ^{c}	9.6±0.1 ^{a}	8.7±0.0 ^{b}	4.4±0.1 ^{e}	4.6±0.0 ^{d}	4.0±0.0 ^{f}
pH	6.9±0.0 ^{d}	7.0±0.0 ^{bc}	7.0±0.0 ^{b}	7.2±0.0 ^{a}	7.0±0.0 ^{b}	6.9±0.0 ^{cd}	7.2±0.0 ^{a}
EC (μS cm^{-1})	185.6±7.7 ^{a}	88.1±1.4 ^{cd}	80.8±1.1 ^{d}	54.0±0.6 ^{e}	97.6±2.7 ^{c}	132.8±3.9 ^{b}	54.4±0.7 ^{e}
Transparency (cm)	26.1±0.7 ^{d}	43.1±1.2 ^{bc}	44.6±1.3 ^{abc}	54.2±2.3 ^{a}	48.4±1.9 ^{abc}	39.2±1.1 ^{c}	51.3±2.7 ^{ab}
Turbidity (NTU)	38.9±1.6 ^{a}	31.1±1.1 ^{a}	32.5±1.4 ^{a}	36.4±2.6 ^{a}	36.6±2.5 ^{a}	33.2±1.5 ^{a}	36.7±2.3 ^{a}
DO (mg O_2 L^{-1})	2.65±0.16 ^{e}	5.92±0.09 ^{c}	6.06±0.07 ^{bc}	7.93±0.08 ^{a}	6.54±0.09 ^{b}	3.86±0.12 ^{d}	7.76±0.08 ^{a}
BOD_5 (mg O_2 L^{-1})	8.22±0.48 ^{a}	1.95±0.06 ^{bc}	1.77±0.06 ^{bcd}	0.77±0.04 ^{e}	1.22±0.06 ^{cde}	2.64±0.11 ^{b}	0.87±0.05 ^{de}
Phosphorus (mg L^{-1})	0.54±0.03 ^{a}	0.19±0.01 ^{bc}	0.16±0.00 ^{cd}	0.08±0.00 ^{e}	0.12±0.01 ^{de}	0.21±0.00 ^{b}	0.08±0.00 ^{e}
Nitrogen (mg L^{-1})	5.96±0.27 ^{a}	2.17±0.07 ^{c}	2.00±0.06 ^{c}	1.29±0.03 ^{d}	1.97±0.05 ^{c}	3.17±0.12 ^{b}	1.26±0.04 ^{d}
TR_{105} (mg L^{-1})	161.1±4.4 ^{a}	104.5±2.2 ^{d}	99.8±1.8 ^{d}	93.8±3.2 ^{d}	118.3±2.9 ^{c}	131.9±2.9 ^{b}	92.8±2.7 ^{d}
Coliforms (NMP $100mL^{-1}$)	$3.8x10^4$±$2x10^3$ ^{a}	$1.5x10^4$±$1x10^3$ ^{b}	$1.2x10^4$±690 ^{b}	210±46 ^{c}	446±117 ^{c}	$2.9x10^3$±249 ^{c}	423±79 ^{c}
N	170	161	161	173	174	173	162

The means (±SE) followed by the same letter (in the comparative between sites) did not differ statistically from each other by the Tukey test at 95% confidence. EC - Electrical Conductivity; DO - Dissolved Oxygen; BOD5 - Biochemical Oxygen Demand; TR105 = Total solid residue at 105°C. N = average number of data per sampling site.

Table 2.

Historical means (2000 to 2011) of metals in surface sediments around the Jacuí's Delta.

Parameters	31 Gravatai River	36 Navegantes	41B Lake Guaiba	57 Jacui River	58 Caí River	59 Sinos River	86A Ilha da Pintada
Al (mg g^{-1})	45.9±3.2 $^{abc\ (1)}$	54.3±4.3 ^{a}	44.5±5.5 ^{abc}	33.9±2.5 ^{bc}	47.7±3.5 ^{ab}	30.4±2.9 ^{c}	31.5±2.9 ^{bc}
Fe (mg g^{-1})	28.6±2.9 ^{b}	38.4±1.9 ^{b}	34.4±4.6 ^{b}	36.3±3.5 ^{b}	52.5±2.9 ^{a}	30.6±2.9 ^{b}	32.2±1.8 ^{b}
Ca (mg g^{-1})	-	3.6±0.2 ^{a}	1.9±0.3 ^{b}	-	-	-	2.3±0.2 ^{b}
Mn (mg kg^{-1})	276.4±12.4 ^{d}	484.7±36.0 ^{bc}	423.6±40.8 ^{cd}	661.7±48.6 ^{b}	929.2±42.4 ^{a}	438.6±31.8 ^{cd}	539.3±62.7 ^{bc}
Ba (mg kg^{-1})	179.1±11.5 ^{ab}	196.0±11.4 ^{a}	138.7±16.9 ^{bc}	196.9±11.2 ^{a}	229.0±9.4 ^{a}	121.9±9.1 ^{c}	187.5±14.7 ^{ab}
V (mg kg^{-1})	-	120.0±10.6 ^{a}	72.5±13.7 ^{a}	60.0 $^{(2)}$	-	-	110.4±11.4 ^{a}
Zn (mg kg^{-1})	295.8±19.8 ^{a}	347.7±16.7 ^{a}	131.3±16.4 ^{b}	79.3±5.1 ^{c}	141.1±8.4 ^{b}	172.5±15.0 ^{b}	74.5±4.6 ^{c}
Cu (mg kg^{-1})	64.3±4.7 ^{b}	103.5±6.2 ^{a}	41.0±6.7 ^{c}	52.4±5.0 ^{bc}	65.5±4.5 ^{b}	43.2±3.7 ^{c}	39.2±3.1 ^{c}
Pb (mg kg^{-1})	50.0±4.2 ^{a}	62.7±4.6 ^{a}	26.1±3.7 ^{b}	20.7±3.4 ^{b}	29.9±3.5 ^{b}	19.7±3.5 ^{b}	24.8±2.9 ^{b}
Cr (mg kg^{-1})	33.1±3.6 ^{b}	51.8±3.6 ^{a}	22.1±2.8 ^{bc}	21.6±1.7 ^{bc}	51.1±4.8 ^{a}	54.4±4.4 ^{a}	18.0±1.2 ^{c}
Ni (mg kg^{-1})	22.8±2.1 ^{b}	37.3±2.5 ^{a}	18.9±2.5 ^{b}	22.9±2.3 ^{b}	42.2±2.9 ^{a}	26.2±2.6 ^{b}	20.8±2.0 ^{b}
Co (mg kg^{-1})	-	28.5±1.8 ^{a}	15.3±2.0 ^{b}	15.0 $^{(2)}$	-	-	21.6±1.6 ^{b}
Li (mg kg^{-1})	-	14.8±1.1 ^{a}	8.2±1.5 ^{b}	-	-	-	8.3±0.7 ^{b}
Be (mg kg^{-1})	-	2.53±0.30 ^{a}	2.11±0.34 ^{a}	1.00 $^{(2)}$	-	-	2.26±0.33 ^{a}
Cd (mg kg^{-1})	0.22±0.02 ^{a}	0.25±0.04 ^{a}	0.21±0.03 ^{a}	0.25±0.03 ^{a}	0.29±0.04 ^{a}	0.20±0.03 ^{a}	0.23±0.03 ^{a}
Hg (mg kg^{-1})	0.16±0.01 ^{b}	0.43±0.04 ^{a}	0.12±0.02 ^{bc}	0.05±0.00 ^{c}	0.08±0.01 ^{bc}	0.16±0.02 ^{b}	0.06±0.00 ^{c}
As (mg kg^{-1})	ND	ND	ND	ND	ND	ND	ND
Ag (mg kg^{-1})	ND	ND	ND	ND	ND	ND	ND
N	16	16	17	17	16	17	16

(1) The means (±SE) followed by the same letter (in the comparative between sites) did not differ statistically from each other by the Tukey test at 95% confidence. (2) No repetitions. ND = not detected. N = average number of data per sampling site.

According to the Brazilian reference values for surface waters (Table 3), Conama No. 357 - Class 2 (Conama, 2005), Points 31 (Gravataí River) and 59 (dos Sinos River) surpass the mean values for DO and Coliforms (Table 1). However, self-purification re-establishes the DO levels in the Navegantes Channel (36), but does not reduce the coliform levels below the resolution limits.

According to the Brazilian reference values for dredged sediments (Level 1) of Conama No. 454 (Conama, 2012), the mean values were above the limits proposed in sediment for Zn (at Points 31, 36, 41B, 58, and 59), Pb (31 and 36), Cr (36, 58, and 59) and Hg (36). The site that presented the most values above the limits (besides the highest concentrations) was 36 (Navegantes Channel), where the water flow from all those rivers accumulates. Sites 57 (Jacuí River) and 86A (Ilha da Pintada Channel) did not present any values above the proposed limits. Site 41B (Lake Guaíba) only presents the concentrations of Zn above the limit.

The association of the analyzed parameters is corroborated by the correlation (r) of their attributes. The increase in P and N concentrations leads to an increase in BOD_5 (0.72 and 0.70, respectively; p<0.05), which in turn reduces DO concentrations (-0.62; p<0.05). This chain reaction occurs by the eutrophication of the water, consuming the oxygen available for the decomposition of the organic compounds from urban pollution (Andrade and Giroldo, 2014).

Previous studies in the Jacuí's Delta and Lake Guaíba show seasonal variations and the negative influence of pollution on river water quality and phytoplankton composition (Rodrigues et al., 2007; Andrade et al., 2012; Andrade and Giroldo, 2014). These studies point to the Gravataí River outflow (Point 31) as a highly degraded point relative to other points, as can be seen in the cluster analysis (Figure 2a).

Considering the historical values, the time (years) and the seasonality (months) had influence on the water parameters (Table 3) in Lake Guaíba (site 41B). Time (years) presents correlations (r) with the depth (-0.80), pH (-0.73), and electrical conductivity (0.73); and the air temperature (seasonal variation in the months) presents correlations (r) with the depth (-0.86), pH (0.83), dissolved oxygen (-0.85) and phosphorus (-0.80). The monthly variations (depth, pH, DO, and P) can be explained by the rainy seasons, with more rainfall in the winter (Aug - 140 mm) and less between the summer-autumn (Apr - 86 mm), influencing the water flow in the lake (Porto Alegre, 2017a). The reduction in the depth through the years (2000-2014) is natural, due to the deposition of sediments. However, the reduction of pH and increase of electrical conductivity (EC) probably occurred due to pollution.

Time (years) influenced the sediment (Table 4), reducing the concentration of some elements (Ca, Mn, Ba, V, Pb, Co, Li, Be, and Hg). The reduction in values of Pb (r -0.90; R^2 0.80) and Hg (r -0.82; R^2 0.67) is especially significant given the high toxicity of both metals. This decrease occurred throughout the world by the environmental pressure to control these priority metals (Bing et al., 2016).

The Rivers Caí, Gravataí, and Sinos are publicly known for their pollution, flowing through industrial areas in a metropolitan region, suffering many environmental impacts. Thus, the remediation and protection of Jacuí's Delta and Lake Guaíba are made even more complex by the liabilities upstream.

Table 3.

Historic data (means) of water parameters in the site 41B - Lake Guaíba.

Parameters	air	water	depth	pH	EC	Secchi	Turbidity	DO	BOD_5	P	N	TR_{105}	Coliforms
dates	°C	°C	m	-	µS cm^{-1}	cm	NTU	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	MPN
2000	20.7	21.2	10.5	7.4	79.9	27.9	47.0	6.19	1.72	-	2.15	112.2	12,575
2001	23.1	22.2	10.4	7.2	73.3	31.7	38.4	5.68	1.66	-	2.40	103.6	13,575
2002	21.7	21.0	10.8	7.2	72.1	35.8	32.6	6.32	1.63	0.14	1.58	97.4	10,191
2003	22.8	22.1	10.3	7.0	77.9	36.8	36.9	5.65	1.44	0.19	1.77	91.0	7,339
2004	20.4	21.1	9.8	6.9	80.5	48.8	27.7	6.37	2.01	0.15	1.66	92.0	9,591
2005	21.4	21.3	9.2	7.1	84.3	52.5	25.1	6.46	2.15	0.14	1.78	99.4	12,091
2006	21.3	21.5	9.5	7.1	82.3	53.3	27.2	6.24	2.01	0.15	2.40	90.7	11,308
2007	21.6	21.3	9.3	6.8	77.7	44.6	31.9	5.88	1.65	0.15	2.15	112.3	11,083
2008	19.5	21.2	9.4	7.0	79.8	46.7	29.4	5.95	1.87	0.19	1.95	104.3	14,854
2009	20.6	21.2	9.4	7.0	80.8	46.3	31.0	6.06	1.55	0.15	1.97	99.7	13,308
2010	19.6	20.3	9.5	7.1	80.4	40.0	32.0	6.38	1.48	0.17	1.84	93.7	13,366
2011	21.0	20.6	8.7	6.8	79.7	41.3	36.4	6.26	1.95	0.18	2.47	93.3	19,250
2012	22.0	22.0	8.7	7.0	92.9	53.8	28.6	5.72	2.28	0.15	2.56	104.7	9,336
2013	19.5	20.7	8.5	6.9	88.1	44.5	29.3	5.72	1.51	0.15	2.04	99.4	14,872
2014	17.3	17.8	9.7	6.9	88.6	36.7	40.4	5.60	1.05	0.14	2.08	113.5	6,750
r_{year}	-0.62	-0.57	-0.80	-0.73	0.73	0.41	-0.26	-0.29	-0.16	-0.01	0.29	0.10	0.14
Jan	27.2	27.1	9.3	7.2	75.5	48.2	25.9	5.79	1.59	0.14	1.82	92.3	9,743
Feb	26.5	27.2	9.3	7.2	81.4	49.3	22.3	5.84	1.82	0.12	1.76	82.7	10,057
Mar	26.2	25.7	9.3	7.1	76.2	50.0	24.4	5.64	1.63	0.13	1.54	96.1	10,621
Apr	22.0	22.6	9.2	7.1	84.3	54.6	25.2	6.02	1.72	0.14	1.58	86.7	10,909
May	18.0	18.3	9.7	6.9	84.1	51.3	25.1	6.33	1.48	0.15	1.85	100.1	12,260
Jun	17.0	16.0	9.9	7.0	85.3	43.5	30.8	6.69	1.70	0.18	2.10	101.6	16,115
Jul	13.3	14.8	9.8	6.9	86.9	37.5	47.3	6.86	2.35	0.20	2.48	110.4	13,564
Aug	16.7	15.8	9.7	6.9	81.1	37.9	35.0	6.56	1.70	0.17	2.30	108.4	11,179
Sep	17.1	17.7	9.9	7.0	78.3	32.5	41.0	6.23	1.91	0.17	1.96	105.4	13,254
Oct	20.6	20.7	9.8	6.9	76.6	34.7	45.0	5.57	1.69	0.18	2.19	111.2	13,847
Nov	23.9	23.7	9.4	7.1	80.6	33.9	41.2	5.53	1.82	0.17	2.30	101.9	11,577
Dez	23.5	24.9	9.5	7.1	79.6	43.2	26.4	5.71	1.90	0.16	1.82	99.9	14,700
$r_{air\ °C}$	-	0.99	-0.86	0.83	-0.62	0.45	-0.60	-0.85	-0.43	-0.80	-0.65	-0.71	-0.59
Conama No. 357	-	-	-	6 - 9	-	-	100	5	5	0.05	3.7	-	1,000

Table 4.
Historic data (means) of metals in surface sediments in the site 41B - Lake Guaíba.

Year	Al	Fe	Ca	Mn	Ba	V	Zn	Cu	Pb	Cr	Ni	Co	Li	Be	Cd	Hg
	mg g^{-1}			mg kg^{-1}												
2000	45.8	57.0	2.7	680	275	130	218	81.0	49.0	38.5	23.0	23.0	18.0	4.0	0.30	0.25
2001	72.4	47.7	2.8	696	220	185	219	-	50.0	40.5	36.5	27.0	17.5	3.5	0.25	0.24
2002	69.5	47.1	2.8	695	-	130	209	-	30.0	39.0	42.0	33.0	13.0	4.0	0.10	0.21
2003	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2004	27.3	25.5	1.7	425	140	75	93.0	-	25.0	11.0	16.5	13.5	6.00	1.5	0.30	0.08
2005	13.6	15.3	1.3	281	85	35	83.0	28.0	30.0	9.5	11.0	11.5	2.00	1.0	0.10	0.08
2006	13.6	18.5	1.2	317	80	30	70.5	28.5	25.0	13.0	12.0	10.0	2.50	1.0	0.20	0.07
2007	33.6	28.3	1.0	505	175	70	125	49.0	10.0	22.0	19.5	14.0	9.50	2.0	0.10	0.06
2008	40.7	34.4	-	335	140	40	212	68.0	13.0	33.5	27.5	18.5	8.00	1.0	0.30	0.14
2009	84.9	-	-	313	93	24	65.5	27.1	11.4	14.5	9.19	5.50	4.50	-	0.16	0.08
2010	48.5	-	-	214	75	20	58.2	28.0	10.3	12.0	8.21	5.14	3.78	0.6	0.17	0.04
2011	60.1	-	-	249	70	20	78.0	23.0	16.0	14.0	9.00	6.00	4.00	1.0	0.10	0.07
R^2	0.00	0.54	0.92	0.76	0.66	0.76	0.47	0.44	0.80	0.42	0.47	0.67	0.59	0.72	0.15	0.67
r	0.02	-0.74	-0.96	-0.87	-0.81	-0.87	-0.69	-0.66	-0.90	-0.65	-0.69	-0.82	-0.77	-0.85	-0.39	-0.82
mean	46.4	34.2	1.93	428	135	69.0	130	41.6	24.5	22.5	19.5	15.2	8.07	1.96	0.19	0.12
±se	7.1	5.3	0.31	56	22	16.9	21	7.8	4.4	3.8	3.5	2.8	1.74	0.43	0.03	0.02

No detection for As and Ag. No differences between months. R^2 - coefficient of determination; r - correlation coefficient; ±se - standard error.

4. CONCLUSIONS

The historical data of water and sediment around the Jacuí's Delta shows the influence of the tributaries with low quality in the downstream points. The pollution of the Rivers Caí, Sinos, and Gravataí negatively affect the environmental quality of Navegantes Channel and Lake Guaíba (catchment points to water supply). The water in those sites present reductions in dissolved oxygen and high values of coliforms, and the sediment shows high concentrations of metal Zn, Pb, Cr, and Hg. Despite a reduction in past years in Pb and Hg values in the sediment, pollution from the tributary rivers persists.

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