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Evaluation of the Una River Basin-Pernambuco: Water Quality Perspective after Construction of 4 Flooding Containment Dams

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A B S T R A C T

The socioeconomic and environmental damages caused by recurrent floods in the Una River Basin in Pernambuco has instigated a flood containment plan elaboration through dams construction. This work evaluated the main factors related to water quality that could interfere with the multiple uses of the reservoirs futures after dams construction. The parameters of water quality evaluated, in the period between 2014-2015, were: Cobalt total, dissolved Copper, total Copper, total Chromium, dissolved Iron, dissolved Aluminium, Fluoride, total Uranium, total Vanadium, total Zinc, total Lithium, total Manganese, dissolved Mecury, total Mercury, Nickel, Silver, total Selenium, Sulphates, Sulfide, Nitrates, total Phosphorus, Dissolved Oxygen, Biochemical Oxygen Demand (BOD), pH, Total Dissolved Solids (TDS), electrical conductivity, Temperature and Turbidity. The results indicated, as major factors interfering in water quality: sewage release in nature causing elevation of BOD; leachate agricultural fertilizers causing high Phosphorus concentration and natural features of the soil of the region causing high Iron concentration. No traces of the presence of Cobalt, Chromium, Selenium, Uranium, Vanadium and total Zinc, Silver, Copper and total and dissolved Mercury were found. The results pointed to the need to control actions of the activities anthropogenic pollutants on the banks of the waterways of the Una River Basin, particularly in view of serve water for public supply.

Keywords: Dam; Land use and occupation; Water quality parameter.

Introduction

Anthropogenic activities, such as agriculture, sewage disposal, dam construction, etc., have a direct impact on water quality causing damage to water sources. Climate change can also influence water quality in an indirect way.

The climate causes changes in precipitation regime, air temperature and incidence of solar radiation. These factors alter the water quality through changes in the flow regime and temperature, which in turn significantly influence biochemical processes (Rehana and Mujumdar, 2012). Most of the deep impacts on water quality are intensified by temporal conditions (Michalak, 2016).

Historically, the region of the Mata Sul in the state of Pernambuco, has been affected by extreme climatic events with a high volume of precipitation in short time intervals. In addition to the rainy season, the region's topography favours major flooding. The most recent events occurring in 2000, 2005, 2010, 2011 and 2017 caused great economic damage, as well as human loss. Because of these climatic events, efforts were made to construct five dams along the Una River, Mundaú River and Sirinhaém River, to allow the containment of floods and simultaneously serve the public supply. At the beginning of 2017, only the Serro Azul Dam, located on the Una River, was in the process of being finalized.

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Since the last extreme rainfall events recorded in the early 2000s, research on the main river basins bordering the region of the Mata Sul in the state of Pernambuco has been recurrent (Silva et al., 2009; Silva, Nobrega, Galvíncio, 2009; Galvíncio, 2010; Cardoso et al., 2013; Santos, Assis, Souza, 2014).

The Una River Basin is the main river basin in the region. It has a large irregularity in precipitation, ranging from 800 mm in the western sector of the basin to 2200 mm in the eastern sector. The highest rainfall rates in the region were recorded in four months of the year, from April to July, with July being the rainiest (maximum precipitation of approximately 160 mm). On the other hand, in the dry season, which comprises the period of October to December, November is considered the driest (averaging 25 mm of precipitation).

Considering a global warming scenario discussed by Albuquerque and Galvincio (2010), it is possible to project the reflections of climatic changes in the socio-spatial organization of the Una River Basin with a possible increase in surface runoff. If this trend is confirmed by the scenario, according to the authors, the problems already encountered in the basin during the rainy season may intensify. Problems related to floods will become increasingly common and will cause loss and fatalities in the major cities bordering the Una River Basin.

According to information provided by the Secretary of Water Resources and Energy of the State of Pernambuco (SRHE-PE), four of the five dams planned in the region of Mata Sul will be built in the Una River Basin: Igarapeba, Lagoa dos Gatos, Panelas II and Serro Azul.

Dams are structures designed to hold liquids in a controlled and safe manner, providing important benefits. Dams have made life a lot easier for societies, whether for flood control, power generation, transportation, water supply, etc. Currently, about 45,000 dams have barred around 60% of the surface water that would drain into the oceans (Nilsson et al., 2005).

On the other hand, the construction of such engineering structures, according to Nilsson et al. (2005), can generate several negative impacts such as: fragmentation of habitats due to preventing gene flow between species; modification of ecosystem dynamics; eutrophication; contamination of aquifers; changes in soil quality; changes in surface and underground water quality; and consequently, interference in its various uses; change in the depth of the euphotic zone; and decrease of dissolved oxygen, etc.

Therefore, undertaking environmental diagnosis before the construction of the dams is of paramount importance in identifying the problems caused by the human interference and impacts on the water resources, and providing a prognosis and mitigation with environmental compensation measures. Among the activities of diagnosis and minimization of impacts, the monitoring of water quality in reservoirs appears an important instrument in subsidising actions of control, and has been a focus of studies (Silva et al., 2009; Buzelli and Cunha-Santino, Gupte, Shaikh, 2013; Palma et al., 2014; Neves et al., 2016).

In view of the purpose of dams in the Mata Sul region, which includes the containment of floods and public water supply, the main objective of this work was to evaluate the water quality in points close to the axis predicted in the dam's projects. The work also aims to identify the main intervening factors in the water quality, aiming to subsidize decision-making in the integrated water management of the basin.

Materials and methods

Study area

This study was carried out in the Una River Basin, located in the region of Mata Sul in the state of Pernambuco, Brazil. The basin is located between the co-ordinates 8 ° 17'14 "and 8 ° 55 '28' 'south latitude, and 35 ° 07'48"' and 36 ° 42'10 "longitude west (Figure 1). The Una River is the main watercourse in this basin. It has approximately 290 km of extension, with its source in the municipality of Capoeiras. It presents an intermittent regime until near the city of Altinho, where it then becomes perennial.

In terms of multiple uses, the Una River does not differ from the others in the region of Mata Sul, with the following predominant purposes: public supply, animal watering, industrial use, irrigation with emphasis on sugar cane cultivation, as well as activities of leisure and fishing. Throughout its course, the river serves as a receiving water body for domestic, industrial and agroindustry effluents.

Among other aspects, we highlight the importance of the Una River Basin to Pernambuco: about 23% of the state's municipalities are included in this river basin (42 of 185 existing ones), the basin occupies approximately 7% of the area of the State (6,740 km² of the existing 98,076 km²) and covers about 15% of the total population of Pernambuco, taking into account the population of the municipalities that are part of the area of influence of this basin (IBGE, 2016).

Figure 2 shows the unilateral diagram of the Una River. The watercourses evaluated in the present study were: Pirangi River (R-1), Una River (R-2), Gatos Stream (R-3) and Panelas River (R-4). The major cities bordering the rivers were also added.

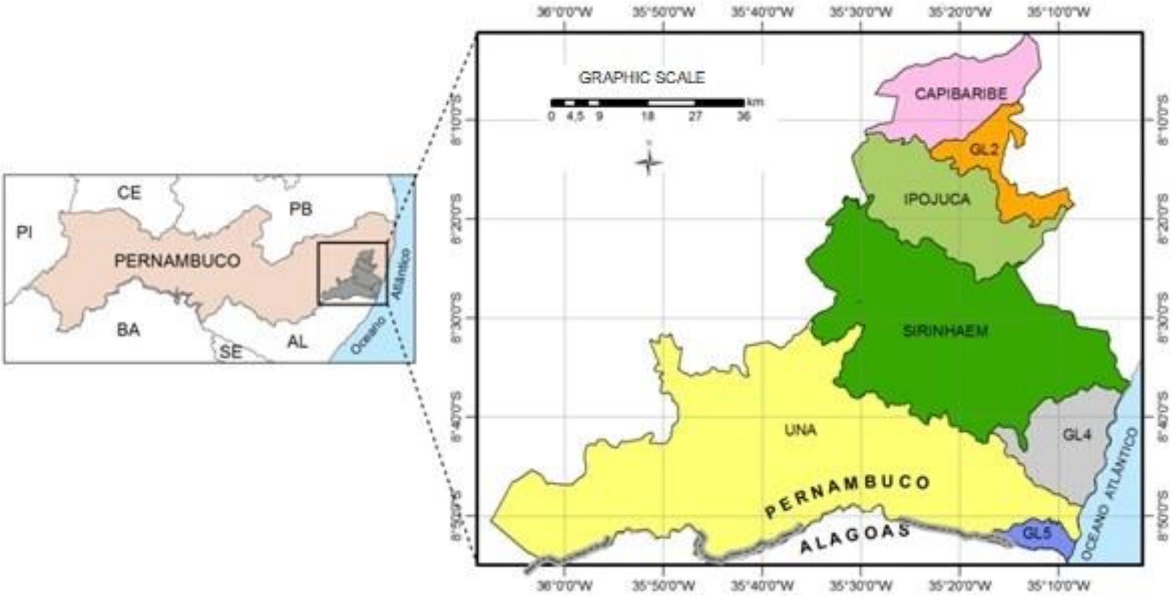

Figure 1. Map of Pernambuco state highlighting the hydrographic basins that make up the Zona Sul Mata Pernambucana (Source: AGEITEC, 2017).

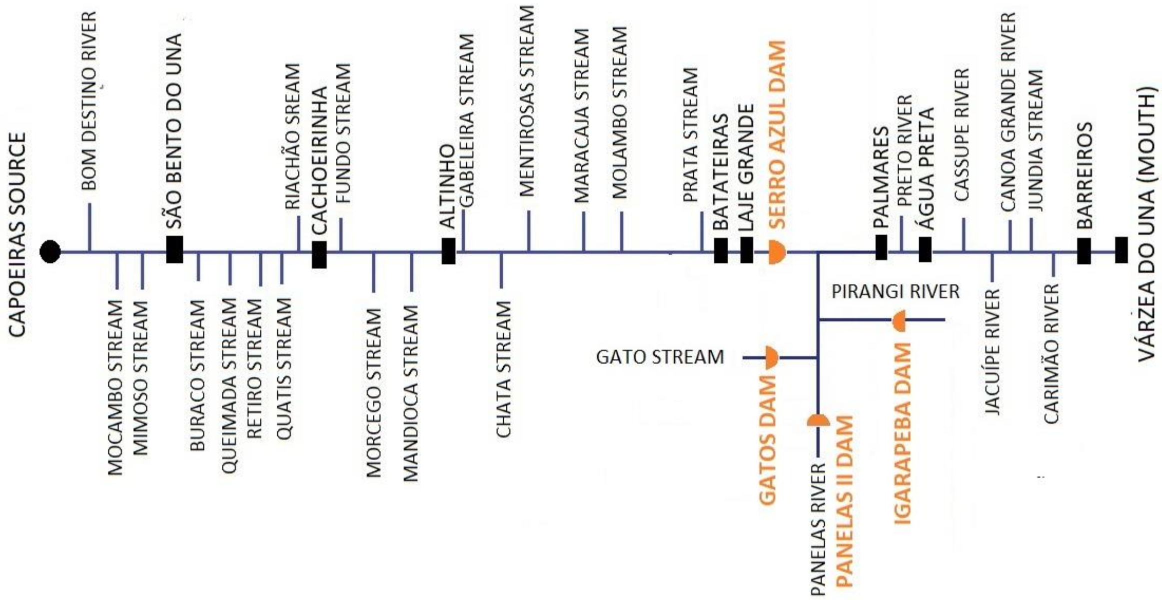

Figure 2. Unilateral Diagram of the Una River highlighting the watercourses studied.

Water sampling and treatment

To evaluate the water quality, collection points were chosen equidistant and close to the axis foreseen in the dam project. The only dam that is being finalised is the Serro Azul dam, which is located in the Una River, the others are in different stages of construction.

The studied watercourses were denominated as follows: R-1 (Pirangi River), R-2 (Una River), R-3 (Gatos Stream) and R-4 (Panelas River). Different number of points were evaluated in the rivers in total. We evaluated eight points in the Pirangi River and Una River, four points in the Gatos Stream and 7 points in the Panelas River. Two collection campaigns were carried out, which occurred between March 2014 and April 2015, thus totaling 54 samples.

Table 1 shows information about the geographical coordinates of the water collection points in the rivers of the Una basin where the Igarapeba, Serro Azul, Gato and Panelas II dams will be built.

The water samples were collected on the surface of the water bodies at each point and followed the procedures defined in the National Collection and Preservation Guide for Sampling of the National Water Agency of Brazil – ANA, and the

Environmental Company of the State of São Paulo – Cetesb (CETESB, 2011).

We evaluated the following parameters: total cobalt, dissolved copper, total copper, total chromium, dissolved iron, fluorides, silver, total selenium, total lithium, total manganese, dissolved mecury, total mercury, nickel, total uranium , total vanadium, total zinc, sulphates, sulphide, nitrates, total phosphorus, dissolved oxygen, pH, electrical conductivity, total dissolved solids, temperature, and turbidity. The procedures were performed according to the methodologies recommended by the Standard Methods for the Examination of Water and Wastewater (APHA, 2012).

Table 1. Water collection points in the rivers of the Una-PE.

Watercourses	Geographical Coordinates (UTM)							
	R-1 (Pirangi River)		R-2 (Una River)		R-3 (Gatos Stream)		R-4 (Panelas River)	
Dams	Igarapeba		Serro Azul		Lagoa dos Gatos		Panelas II	
Water collection points	E	N	E	N	E	N	E	N
1	177202	9024163	199644	9049031	184546	9045892	177041	9049013
2	178149	9024082	203755	9048575	184300	9045562	179359	9048948
3	180347	9025900	204484	9049551	185876	9046041	181014	9048886
4	181258	9025649	205581	9049785	186424	9046154	180985	9048368
5	183113	9025784	206844	9049221	-	-	181767	9047208
6	183387	9025547	209513	9048400	-	-	183199	9048108
7	183757	9025112	209538	9046395	-	-	185730	9046928
8	184256	9025352	211690	9043777	-	-	-	-

In order to interpret the results, they were evaluated considering the maximum and minimum limits of the standards defined for rivers Class 2, recommended by CONAMA Resolution 357/2005 (Brazil, 2005), since the water bodies studied do not have a defined class according to the Brazilian resolution above.

Results and discussion

Figures 3a and 3b show respectively, the temperature variation and pH values of the water in the four watercourses studied (R-1, R-2, R-3 and R-4). According to Angelocci et al. (1995), the water temperature is an important monitoring parameter due to the physical control, chemical and biological processes. In this study, the water temperature varied from 22.2 °C to 31.9 °C, according to typical temperatures of the region and influenced directly by climatological conditions. Several studies, such as those developed by Vidal and Capelo Neto (2011), Wachholz (2011), Franzen et al. (2011), Mannich et al. (2013) and Huang et al. (2014), show that the water temperature stratification is one of the first impacts produced by reservoir construction. This causes significant changes in the physical chemical variables in the water column and therefore, influences the quality of the water in these lotic environments.

Regarding pH (Figure 3b), although the levels varied within the limits established by Brazilian Legislation (CONAMA Resolution 357/2005), 80% of the samples analysed had slightly acidic pH values below 7. These observations may be associated with several untreated sewage disposal points observed along the springs, especially in R-1 (Pirangi River) and R-2 (Una River), where the areas of direct influence are the Igarabeba and Serro Azul dams.

Marotta et al. (2008) suggests that pH level oscillation in spring waters could be a result of organic matter excess in sewage, which can cause a reduction in the pH of the water through the release of carbonic acid, as well as organic acidic compounds.

In addition, such pH oscillations in the waters may also reflect the natural characteristics of the environment. Through a study on the catchment area of the Caiabi-MT River, Andrietti et al. (2016) observed average values of pH around 5. According to the authors, the low pH value was not justified by the use and occupation of the soil, but by the natural condition of the Caiabi River Basin, mainly because the soils of the region are old undergoing a high leaching process.

Previously, studies by Ferreira and Cunha-Santino (2014) recorded acidic pH values (between 5.0 and 6.7) in the waters of the Monjolinho River, in the Brazilian Cerrado region, which were attributed to the natural characteristics of the region (acidic soils), however, Andrietti et al. (2016) disregarded the anthropic influence in the results. As mentioned earlier, during the collection campaigns in the Una River Basin, it was possible to observe several cases of domestic sewage disposal, which can certainly interfere with the natural characteristics of the water bodies studied.

According to Lima and Garcia (2008), monitoring of water pH should always be evaluated because it may interfere with the water treatment process, cause corrosion of pipes and equipment, and affect the microbial growth of biological treatment systems, and toxicity of certain compounds in the constituents of alkalinity, acidity and water.

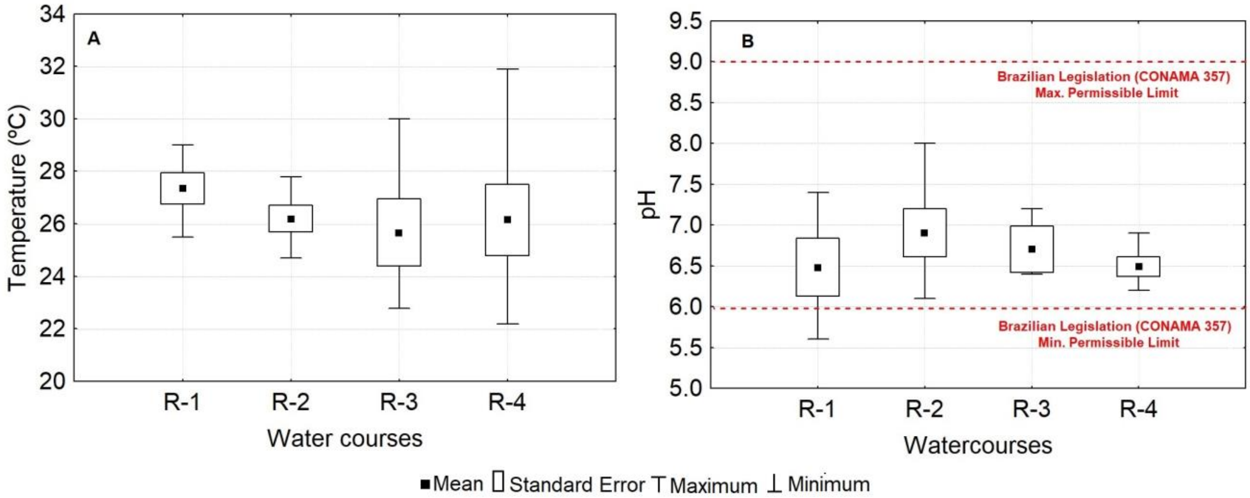

Figure 3. Temperature (A) and pH values (B) in the four evaluated watercourses, in Una River Basin (R-1 = Pirangi River, R-2 = Una River, R-3 = Gatos Stream, R-4 = Panelas River).

Figures 4a and 4b show the results of the turbidity variation and Total Dissolved Solids in the four evaluated watercourses. The turbidity of the water represents the attenuation degree of light intensity that suffers when crossing it, and this reduction takes place by absorption and scattering. Turbidity can be attributed to the presence of suspended solids, such as inorganic particles and organic debris (CETESB, 2009).

Turbidity values ranged from 1.5 uT to 98.9 uT. Although a high value fluctuation was observed, all observed results were below the maximum limit allowed by the Brazilian environmental legislation (CONAMA 357/2005). In relation to the Total Dissolved Solids (TDS), values were also observed within the legal limit, except for some samples of the Panelas River (R-4) where the area of direct influence of the Panelas dam is located.

Subsequently, it is possible to verify that the Panelas River (within the analysed watercourses), presented the greatest number of parameters outside the limits of values established by the current environmental legislation.

Regarding the discussions of the results obtained in this study, they agree corroborate with those developed by Ferreira and Cunha-Santino (2014) for the Monjolinho River in São Carlos-SP, which also recorded low values of turbidity varying from 4.12 to 23.43 uT, considering dry and rainy periods.

Through water quality monitoring at the Piranhas River in Paraíba State of Brazil, Chaves et al. (2015) found increasing values of turbidity from the dry period towards the rainy season, which was explained by the increase in the movement of the solid particles from the river bottom, as well as the drag of coarse material present in the bed.

The present study considered collection campaigns in both the rainy and dry periods and, in both periods, turbidity and TDS values presented good results, except for the TDS values at the R-4 point.

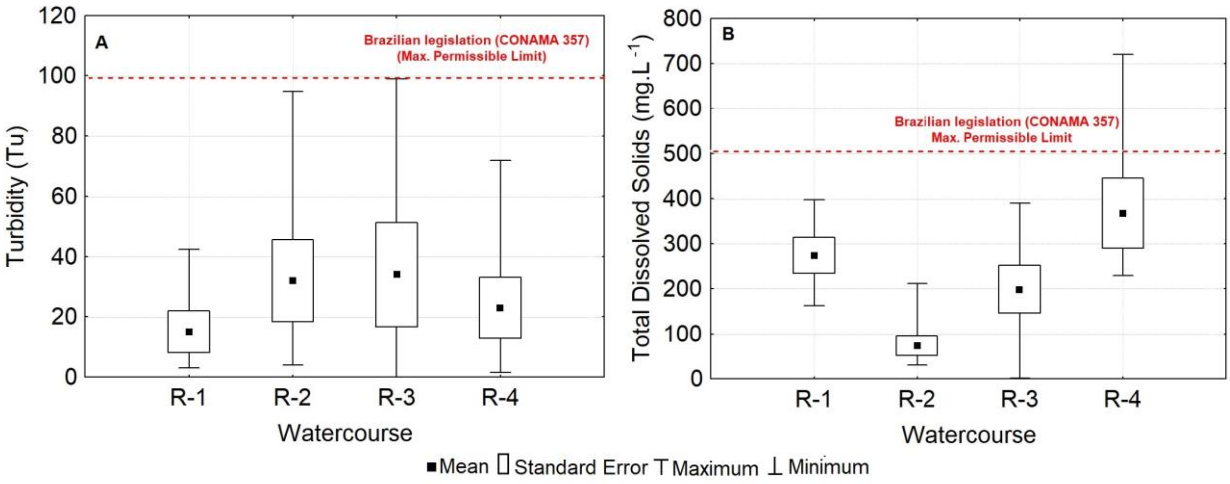

Figure 4. Turbidity and Total Dissolved Solids in the four evaluated watercourses, in Una River Basin (R-1 = Pirangi River, R-2 = Una River, R-3 = Gatos Stream, R-4 = Panelas River).

Figures 5a and 5b show Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) concentrations, respectively. The two main factors that influence the increase of the dissolved oxygen concentration in the water are the gas exchanges with atmosphere. and the photosynthesis performed by the algae.

According to Buzelli and Cunha-Santino (2013), the factors that negatively affect the dissolved oxygen availability are aquatic organisms respiration, the oxidation process of metallic ions, and the aerobic decomposition of organic matter. The DO is indispensable for aerobic organisms and indicates the ability of the body of water to self-purify (Zucco et al., 2012).

In this study, the dissolved oxygen concentrations ranged from 0.9 to 9.5 mg.L^{-1}, with great fluctuations in compliance with Brazilian Environmental Legislation (minimum permissible of 5 mg.L^{-1}). These results showed a tendency contrary to that observed in the study carried out by Zucco et al. (2012) on water quality in the Ribeirão Concórdia basin (Santa Catarina State of Brazil), which found values of dissolved oxygen with little fluctuation and within the limit desired by the legislation.

The R-1 and R-2 watercourses, presented the best dissolved oxygen conditions, both of which are larger and have a higher flow compared to R-3 and R-4, which presented a large sample below the permitted level. The presented study is in line with that of Silva (2010), who observed low DO values near the Três Marias Hydroelectric Power Plant up to the Juazeiro-Petrolina Irrigation Pole, which were associated with the thermal stratification and eutrophication caused by "standing" water. This together with anthropic pollution (fertiliser use and disposal of industrial and domestic effluents) contributes to the DO decrease.

The low DO condition in the present study may be aggravated when the environments become lentic. According to Esteves (1998), the first years after flooding of the dam correspond to the period of greatest oxygen deficit, which makes a prognosis about DO levels important, before, during and after reservoir filling.nIn relation to BOD levels, only points located in R-3 (Gatos Stream), where the dam will be built, presented values below the maximum limit allowed (Brazil, 2005). According to Ferreira (2015), high BOD levels are generally found when organic discharge launches occur.

Throughout the main watercourses of the Una basin several releases of domestic sewage without treatment were found, in addition to diffuse pollution due to the cultivation of sugarcane. The application of vinasse, among other fertilisers in these cultivation regions, causes the leaching of soil compounds to the watercourses during periods of greater rainfall, increasing concentrations of organic matter and nutrients.

In R-3 the low BOD concentration was observed along with a DO oscillation between 1 to 9.5 mg.L^{-1}, which was not expected since the low BOD concentration allows a satisfactory dissolved oxygen condition (above the allowed minimum), at 5 mg.L^{-1}.

Queiroz et al. (2010) suggest that in the Sanga Mandarina-PR microbasin, the low levels of dissolved oxygen observed are initially associated with the organic matter presence, however, no pollution points like releases of animal wastes or domestic sewage were observed in the basin. So, the values were associated with the daily variations of photosynthesis, respiration and /or decomposition.

According to Valente (1997), it is important to understand that BOD is only an indicator that indirectly determines the organic matter's biodegradable concentration through the oxygen demand of microorganism respiration, however, several other processes occur simultaneously in a water body. In their study, DO values inversely proportional to BOD concentrations were also identified

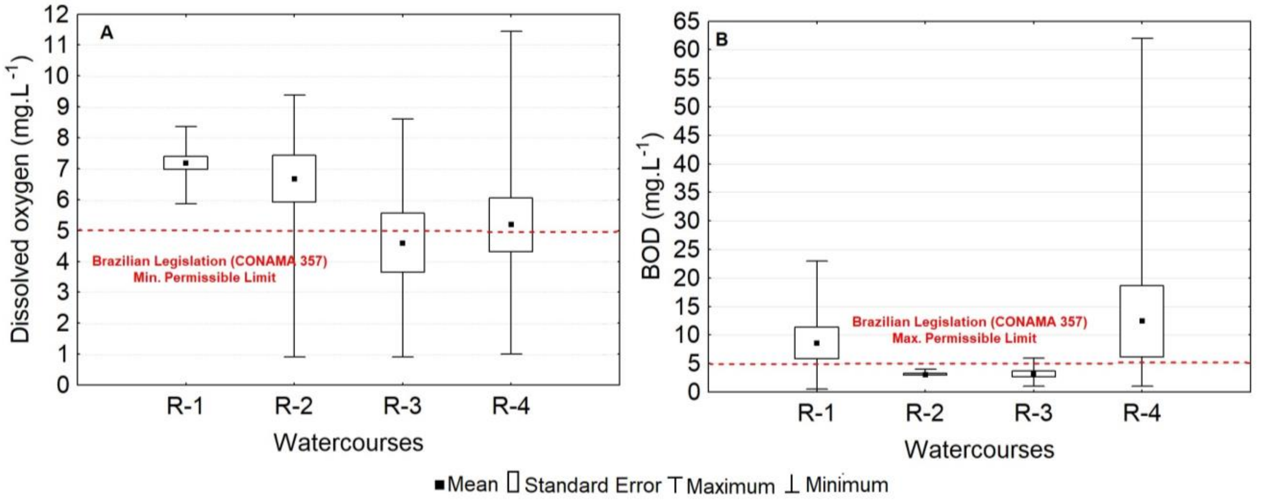

Figure 5. Dissolved Oxygen (A) and Biochemical Oxygen Demand (B) concentrations in the four evaluated watercourses, in Una River Basin (R-1 = Pirangi River, R-2 = Una River, R-3 = Gatos Stream, R-4 = Panelas River).

Figures 6a and 6b show the nitrate and ammonia concentrations observed whilst monitoring the bodies of water studied. The results analysis of these two parameters allowed us to infer that all the values were within the limits established by Brazilian Legislation (CONAMA 357/2005). Even with BOD concentrations above the legal limit, there was no ammonification of the environments to raise the ammonia concentration above the established legal limit. Thus, it is not expected with the construction of the dams, and consequent change of environment to lentic, that the reservoirs will present excess nitrogen in the water. On the other hand, high phosphorus concentrations can cause eutrophication favouring toxic algae flowering, especially if the environment varies from lotic to lentic. On this statement, Paerl and Paul (2012) associated toxic ablutions of cyanobacteria with the following abiotic parameters: vertical stratification, high temperature and nutrient availability. Thus, the concern with eutrophication of the watercourses evaluated in this study should be considered so that continue to serve the various uses, mainly after the construction of the dams and change of behaviour of the rivers.

Insofar as the results obtained in this study with other studies, we can see the importance of these water quality monitoring studies in water sources (lentic and lotic), especially those for the public supply. An example of this is the study by Vasco et al. (2011) on the sub-basin of the Poxin River, Sergipe State of Brazil, where the highest concentrations of total phosphorus were observed during the rainy season, with values above the legal limit. This tendency was explained by the superficial deflution occurring in the sub-basin caused by heavy rain. In addition to these results, Zucco et al. (2012) argue that the disordered use and occupation of the soil on the banks of water bodies also contributes significantly to water quality, especially with regard to nutrient and sediment inputs.

Scarpinella et al. (2013), in turn, found that in a small dam located at Fazenda Santo Antonio do Lobo, São Paulo State-Brazil, (which produces sugarcane), there was an increase of nitrogen and total phosphorus levels in the water after rainy events.

On the other hand, studies such as those developed by Queiroz et al. (2013) in the Piancó, Paraiba State-Brazil, which found phosphorus values below the limit for a class 2 river, revealed that the adequate management of the soil in the pasture of the basin and the low solubility of phosphate compounds added to the soil with a strong fixation tendency to help improve phosphorus levels in water bodies.

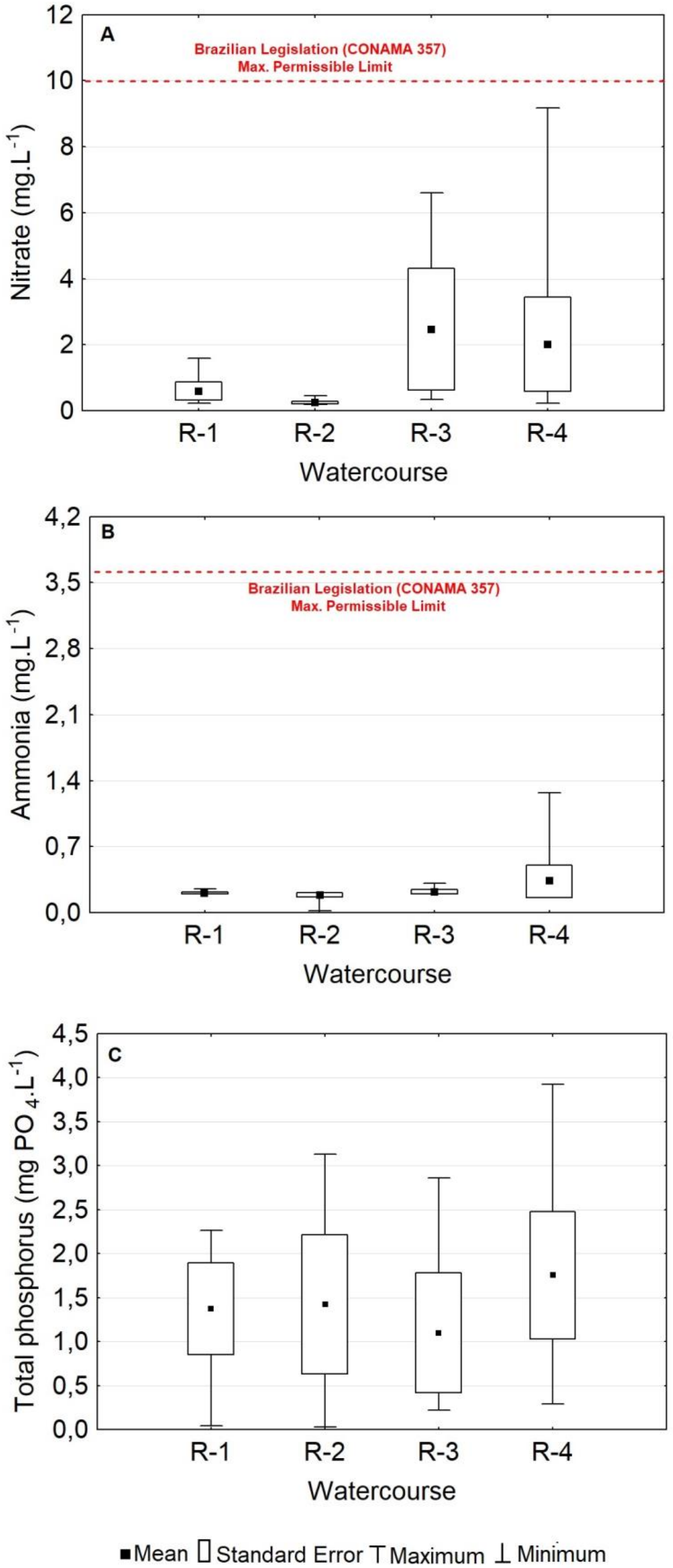

Figure 6. Nitrate (A), Ammonia (B) and Phosphorus (C) concentrations in the four evaluated watercourses, in Una River Basin (R-1 = Pirangi River, R-2 = Una River, R-3 = Gatos Stream, R-4 = Panelas River).

Corroborated by the aforementioned studies, the Una River Basin is largely occupied by agricultural activities (especially sugarcane cultivation in its eastern region), which is associated with the intensive use of fertilisers rich in phosphorus. This may also have contributed to the high concentration of phosphorus in studied watercourses, and may come from the surface runoff and leaching of the soils around the areas where the dams will be built.

The following chemical elements were not observed in any samples evaluated: total cobalt, dissolved copper, total copper, total chromium, lithium, dissolved mercury, nickel, silver, selenium, total uranium, total vanadium. This appears to be a positive result, with no likelihood of increased toxicity from dam construction.

On the other hand, with respect to the other metals evaluated and their variations, Figures 7a, 7b and 7c show variations in dissolved iron, dissolved aluminum and manganese levels between R-1, R-2, R-3 and R-4.

With respect to the dissolved iron concentration, it was possible to observe that the average concentrations of this metal in all sample points were above the standards established by legislation (CONAMA 357/2005), at 0.3 $mg.L^{-1}$ (Brazil, 2005). On average, dissolved iron concentrations were higher in R3 (Gatos Stream), $\cong$ 0.9 $mg.L^{-1}$, where the Gatos Dam will be built.

In surface waters, the iron level increases in the rainy season due to the leaching of soils and the occurrence of erosion processes on the banks of water bodies (CETESB, 2009). Despite this, Oliveira et al. (2006) confirmed that the soils of the studied regions present high levels of iron, which justifies the high concentrations of iron found in the surface waters of R-1, R-2, R-3 and R-4.

In natural waters the pH is governed by the carbonate-bicarbonate-carbon dioxide balance and the higher the pH value, the greater the carbonate and bicarbonate ion concentrations present.

Duc et al. (2013) indicate that the heavy metals dissolved in water are removed by means of carbonate-bicarbonate precipitates. Thus, the increasing pH can cause the heavy metal concentration to decrease in the water by precipitating them. However, the pH of this study was slightly acidic, not favouring this behaviour. Regarding this observation, Fernandes et al. (2012) observed higher iron levels in the summer and fall periods in the Palmital-RJ microbasin, and attributed these values to the influence of the slightly acidic pH of the studied water, since in natural waters the occurrence of iron occurs in the form of iron hydroxide particles or in their organic complexed form, having solubility dependent on pH.

In general, the presence of iron in water from springs that is used for human consumption does not cause health problems, however, it may compromise its quality by affecting colour and taste, as well as causing tissue stains and deterioration (Moruzi and Reali, 2012).

In terms of dissolved aluminum concentrations (Figure 7b), it was possible to verify that a large part of the values were above that allowed by the legislation, which establishes a limit of 0.1 $mg.L^{-1}$ (Brazil, 2005).

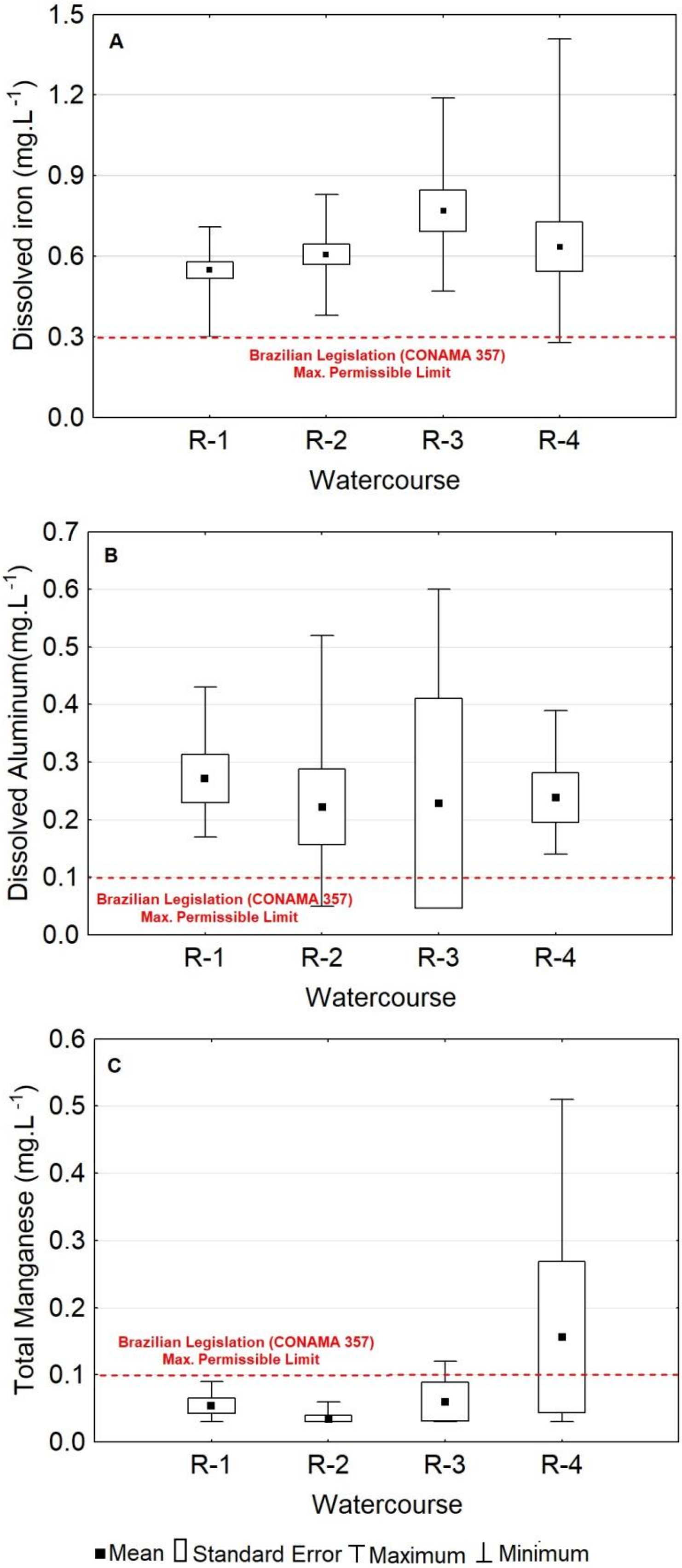

Figure 7. Dissolved Iron (A), Dissolved Aluminum (B) and Manganese (C) concentrations in the four evaluated watercourses, in Una River Basin (R-1 = Pirangi River, R-2 = Una River, R-3 = Gatos Stream, R-4 = Panelas River).

Regarding alumuinium levels in the study environment, research developed by Companhia Ambiental do Estado de São Paulo - CETESB shows that the concentrations of dissolved aluminum in waters with pH 7 vary from 0.001 to 0.05 mg.L^{-1}, but increase to 0.5-1 mg.L^{-1} in more acidic or organic matter-rich waters (CESTESB, 2009), which was the condition observed in the present study. In fact, the concentrations of dissolved aluminum were between 0.1 and 1.0 mg.L^{-1}.

Also the respective chemical element (Al) is considered the most abundant metallic element of the earth's crust, occurring naturally in the environment in the form Al^{3+}, and being redistributed or moved through natural or anthropic activities. It is a neurotoxic compound, and the accumulation of this metal in man has been associated with Alzheimer's disease, a degenerative brain disease of unknown aetiology characterised by the presence of a large number of neurofibrillary structures and senile plaques in certain regions of the brain (Reiber et al., 1995; Freitas et al., 2001).

Regarding the manganese levels observed, a part of the water samples in R-3 (Gatos Stream) and about 80% of the samples in R-4 presented concentrations above the legal limit of 0.1 mg.L^{-1}, established by the legislation (Brazil, 2005).

The manganese concentrations (Mn) are usually present at the water surface at a concentration below 0.2 mg.L^{-1}. However, Mn concentration to 0.5 mg.L^{-1} is well accepted by consumers as it does not present changes in water colour (CETESB, 2009). In the present study, the highest concentration observed was 0.53 mg.L^{-1}.

Corroborating with the Mn levels observed in this study, Oliveira (2006) emphasises that the soils of the Zona Sul da Mata Pernambuco are rich in manganese, which justifies the high concentrations of this metal in the watercourses of the Una basin due to the leaching from soil. In addition to this discussion, Oliveira et al. (2010) evaluated manganese levels in the waters of the Salitre River, in the Bahia-Brazil semi-arid region. After analysing the concentrations of manganese in the dry and rainy period, higher concentrations during the dry period were observed, with values reaching 12 mg.L^{-1}.

Given the importance of planning the operation of reservoirs, aiming to improve water quality, Soraes (2011) evaluated the physical and chemical aspects of the Paraibuna-Paraitinga dam complex, São Paulo, and among other parameters was manganese, which presented levels around 1 mg.L^{-1} (higher than that established by legislation (Brazil, 2005)).

Following this study, Barbosa (2012) monitored the water quality of the Jucazinho reservoir, Agreste Pernambucano, and evaluated the presence of manganese among other parameters. The author observed levels of manganese of about 0.3 mg.L^{-1} in the waters of this reservoir. The results show the recurrence of this metal in Pernambuco reservoirs.

In general, and as observed by Freitas and Almeida (1998), the sources of anthropogenic contamination in surface waters, (such as those observed in the areas where the Igarapeba (R-1) dams will be constructed, Serro (R-2), Gatos Stream (R-3) and Panelas II (R-4)), are generally directly associated with domestic and industrial wastewater and waste from landfills that contaminate groundwater with pathogenic microorganisms. Nordberg et al. (1985) suggest that the mobilisation of metals naturally contained in the soil are aluminum, iron and manganese.

Several crops, which may be associated with the use of fertilisers and agrochemicals, were observed along the R-3 and R-4 watercourses in the areas of direct influence of the future dams of Gatos e Panelas II, respectively, which presented high concentrations of iron, manganese and organic matter.

In addition to the natural characteristics of the environment, the uncontrolled use and occupation of the soil in areas bordered by extensive river basins has directly impacted the quality of its waters. Figures 8 and 9 show the land use and occupation maps in the regions of Gatos Stream and Panelas River, near the axis of the respective dams of Gatos and Panelas II.

By the analysis of the maps it is possible to observe that the river banks are full of agricultural production areas, where the sugarcane monoculture stands out and the use of fertilisers ends up leading to the studied rivers, by leaching, macro and micronutrients, as well as organic matter.

Considering that there is no way to change the natural characteristics of the environments under study, and based on the premise that lotic environments are potential receptors of metals due to their characteristics of depositional environments, they are able to reach very high levels of contamination, according to Esteves (1998). In the future, when the reservoirs provided for in R-1, R-2, R-3 and R-4 are being used as sources for public supply, a treatment for the removal of iron, manganese and aluminum should be provided for in the design of the Water Treatment Plant.

The construction of the Igarapeba, Serro azul, Gato and Panelas II dams in the Una River Basin opens up prospects for many activities, especially for industry, agriculture and livestock. It can exert a major influence on the development and prosperity of the cities where the dams will be built, leading to the creation of an appreciable number of new jobs and related commercial activities. However, its consequences are not always favourable for the upcoming regions.

Integrated and rational planning for the global use of water resources made available from the construction of the respective dams, should not only predict the various uses, but also the consequences for the environment, guaranteeing their integrity and satisfying human needs. Although the multi-purpose planning strategy is politically attractive and commendable, its applicability is often conditioned by strong political and economic constraints. The judgement of its economic viability should not only be based on its direct benefits but also on the benefits derived from the elimination or reduction of damages to the environment.

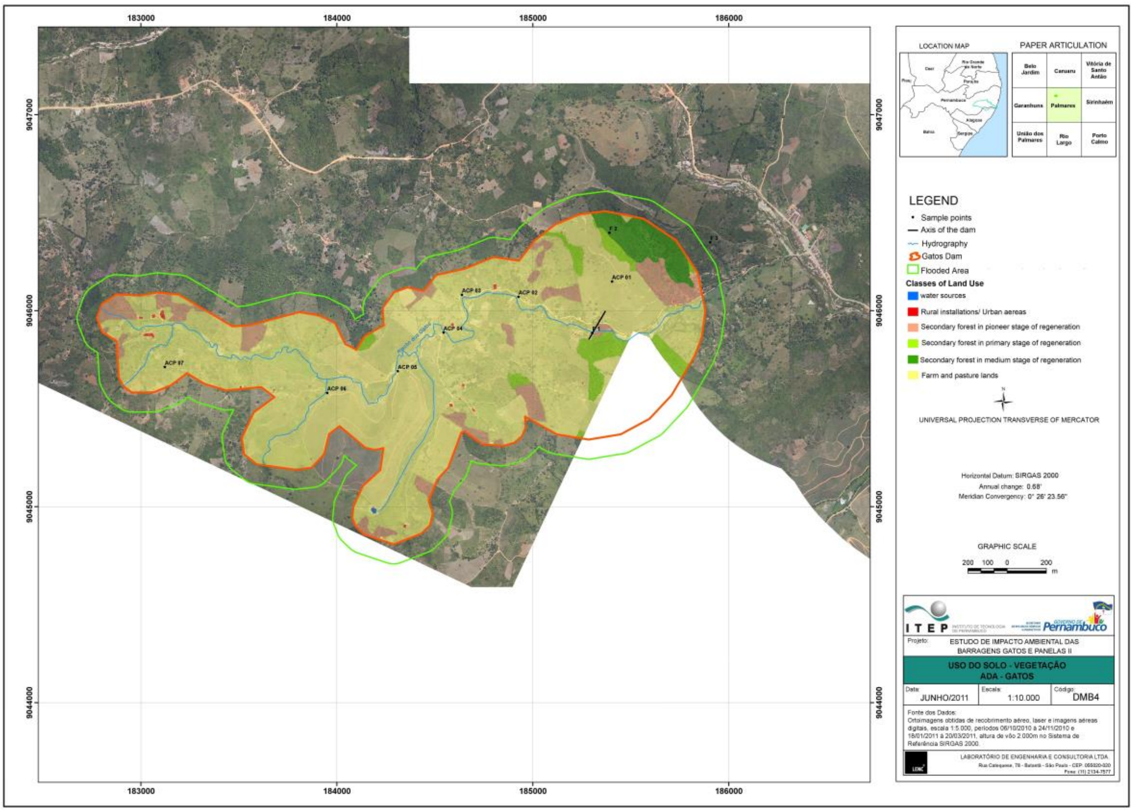

Figure 8**.** Map of Land Use and Occupation of Gatos Stream (R-3) in the area near the axis of the future Gatos Dam (Source: ITEP, 2011a).

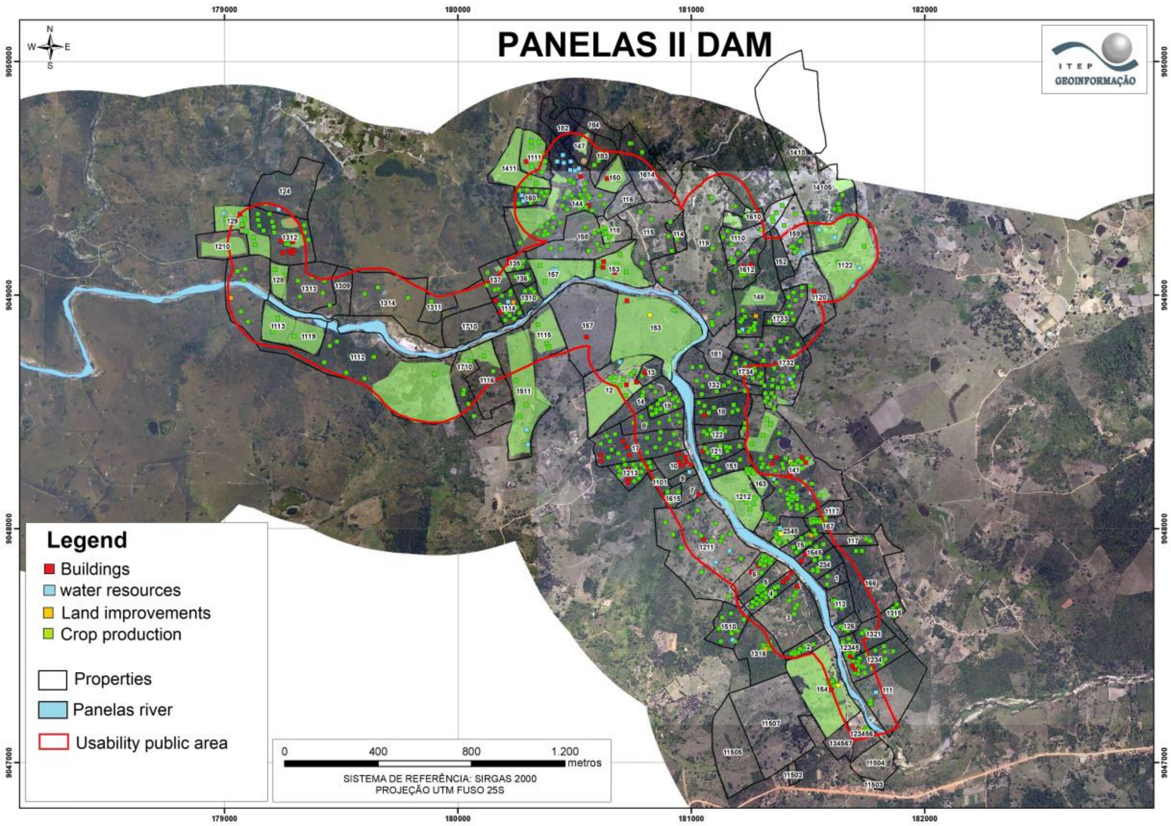

Figure 9. Map of Land Use and Occupation of Panelas River (R-4) in the area near the axis of the future Panelas II Dam (Source: ITEP, 2011b).

Conclusion

The obtained values for turbidity, nitrate and ammonia were within the limit of the pertinent environmental legislation and together with the values found for temperature were typical of those found in the region of the study.

Considering the relation between the evaluated parameters and the damage to water quality, the Panelas River presented the greatest risks with most of the parameters outside the limits recommended in the legislation, except for pH, turbidity, nitrate and ammonia.

The BOD showed concentrations outside the legal limits in R-1, R-2 and R-4, with values that are associated with the untreated sanitary sewage dump in the respective watercourses.

The concentrations of total phosphorus were significantly high compared to the recommended limits, this aspect was associated with the diverse agricultural activities (mainly to the monoculture of sugarcane), in the areas bordering the watercourses. This is a worrying aspect when the waters of the rivers pass into the lentic regime, especially in relation to the possibility of eutrophication and flowering of toxic algae.

The obtained concentrations for iron and manganese were outside the established limits, whose values were attributed to the natural characteristics of the soil of the Una basin. Because it is a natural characteristic, the recommended action is the prediction of units of removal of these elements in the water treatment plant before using as a resource for public supply.

The concentrations of dissolved aluminum were higher than the limits determined, and were bound to the slightly acidic composition of the waters with high concentration of organic material.

The change in the watercourse regime from lotic to lentic tends to intensify pollution and contamination, according to the analysed parameters. The watercourses present a risk of worsening, especially regarding water eutrophication, which reinforces importance of river basin management.

To conclude, the study presented a water quality prognosis in the environments where the Igarapeba, Sero Azul, Gatos and Panelas II dams will be constructed. The absence of planning and monitoring of construction processes and the lack of more detailed studies on the influences of the environmentcan generate serious problems for the public management and authorities when searching for the necessary corrections.

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References

APHA - American Public Health Association. 2012. Standard methods for the examination of water and wastewater. 22 ed. Washington.

Albuquerque, R.T.D.B., Galvíncio, J.D., 2010. Cenários de Mudanças Climáticas na Bacia Hidrográfica do Rio Una – Pernambuco. Revista Brasileira de Geografia Física, 3(2), 48-54.

Alves, J.P.H., Garcia, C.A.B., Oliveira, A., Netto, A., Ferreira, R.A., Santos, D.B., Bezerra, D.S.S., Barbosa, C.D.E.S., Costa, A.S., 2007. Rio Poxim: qualidade da água e suas variações sazonais. Anais Simpósio Brasileiro de Recursos Hídricos. São Paulo: ABRH.. v.17, 1-15.

Andrietti, G., Freire, R., Amaral, A, Almeida, F., Bongiovani, M., Schneider, R., 2016. Índice da qualidade da água e do estado trófico do rio Caiabi, MT, Revista Ambiente e água, 11 (1), 162-175.

Angelocci, L. R. et al., 1995, Variações da temperatura da água de um pequeno lago artificial ao longo de um ano em Piracicaba-São Paulo. Scientia Agricola, 52(3), 431-438.

Barbosa, I.M.B.R. Planejamento da operação de reservatório objetivando a melhoria da qualidade da água: estudo de caso no Agreste Pernambucano. 2012.1-138. Tese (Doutorado) - Programa de Pós-graduação em Engenharia Civil. Universidade Federal de Pernambuco, Recife, Pernambuco.

Brasil, 2005. Resolução Nº 357 de 17 de março. 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. Conselho Nacional do Meio Ambiente: Brasília. Ministério do Meio Ambiente.

Buzelli, G.M., Cunha-Santino, M.B., 2013. Análise e diagnóstico da qualidade da água e estado trófico do reservatório de Barra Bonita-SP. Revista Ambiente & água. 8(1), 186-205.

Cardoso, A.S., Silva Filho, S.M.P., Alves, A.P., Rocha, C.M.C., Cunha, M.C.C., 2013. Fitoplâncton como bioindicador de eventos extremos na bacia do rio Una, Pernambuco, Brasil. Revista Brasileira de Geografia Física, 6(4), 697-710.

Chaves, A.D.C.G., Almeida, R.R.P., Crispim, D.L., Silva, F.T., Ferreira, A.C., 2015. Monitoramento e qualidade das águas do Rio Piranhas. Revista Verde de Agroecologia e Desenvolvimento Sustentável, 10(1), 160-164.

CETESB - Companhia Ambiental do estado de São Paulo. 2009. Qualidade da água interiores no estado de São Paulo: Significado ambiental e sanitário das variáveis de qualidade das águas e dos sedimentos e metodologias analíticas e de amostragem.

CETESB - Companhia Ambiental do Estado de São Paulo - CETESB & ANA-Agência Nacional de Águas. 2012. Guia nacional de coleta e preservação de amostras: água, sedimento, comunidades aquáticas e efluentes líquidos.

Duc, T.A., Loi, V.D., Thao, T.T., 2013. Partition of heavy metals in a tropical river system impacted by municipal waste. Environmental Monitoring and Assessment, 185(2), 1907–1925.

EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária/ AGEITEC-Agência Embrapa de Informação Tecnológica. Disponível em http://www.agencia.cnptia.embrapa.br/gestor/territorio_mata_sul_pernambucana. Acesso: 1 set. 2017.

Esteves, F.A., 1998, Fundamentos de Limnologia. v. 2, Interciência: Rio de Janeiro.

Fernandes. M.M., Ceddia, M.B., Gaspar, M.R., Gaspar, A., Moura, M.R., 2012. Influência do uso do solo na qualidade de água da microbacia Palmital, Macaé–RJ. Revista Verde de Agroecologia e Desenvolvimento Sustentável, 7 (3), 137-142.

Ferreira, C.S., Cunha-Santino, M.B., 2014. Monitoramento da qualidade da água do rio monjolinho: a limnologia como uma ferramenta para a gestão ambiental. Revista de estudos ambientais (Online). 16 91), 27-37.

Ferreira, K.C.D., Lopes, F.B., Andrade, E.M., Meireles, A.C.M., Silva, G.S., 2015. Adaptação do índice de qualidade de água da National Sanitation Foundation ao semiárido brasileiro. Revista Ciência Agronômica, 46(2), 277-286.

Franzen, M., Cybis, L.F.A., Merten, G.H., 2011. Circulação da Água Hipolimnética no Reservatório Divisa do Sistema Salto (RS). Revista Brasileira de Recursos Hídricos, 16(4), 41-48.

Freitas, M.B., Almeida, L.M., 1998. Qualidade da água subterrânea e sazonalidade de organis- mos coliformes em áreas densamente povoadas com

saneamento básico precário. In: X Congresso Brasileiro de Águas Subterrâneas. CD-ROM, São Paulo: Sonopress-Rimo.
Freitas, M.B., Brilhante, O.M., Almeida, L.M., 2001. Importância da análise de água para a saúde pública em duas regiões do Estado do Rio de Janeiro: enfoque para coliformes fecais, nitrato e alumínio. Cad. Saúde Pública [online], 17(3), 651-660.
Huang, T., Li, X., Rijnaarts, H., Grotenhuis, T., Ma, W., Sun, X., Xu, J., 2014. Effects of storm runoff on the thermal regime and water quality of a deep, stratified reservoir in a temperate monsoon zone, in Northwest China. Science of the Total Environment. 485-486(1), 820-827.
IBGE - Instituto Brasileiro de Geografia e Estatística. 2016. Disponível em: http://www.ibge.gov.br. Acesso: 3 mai. 2016.
ITEP – Instituto de Tecnologia de Pernambuco. Estudo de Impacto Ambiental da Barragem de Gatos. 2011a.
ITEP – Instituto de Tecnologia de Pernambuco. Estudo de Impacto Ambiental da Barragem de Panelas II. 2011b.
Lima, W.S., Garcia, C.A.B., 2008, Qualidade da Água em Ribeirópolis-SE: O Açude do Cajueiro a Barragem do João Ferreira. Scientia plena, 4(12), 1-24.
Mannich, M., Bernardo, J.W.Y., Polli, B.A., Zahn, E., Bleninger, T. B., C.V.S., Fernandes., 2013. Análise da estratificação térmica no reservatório Vossoroca através de índices físicos. Anais: XX Simpósio Brasileiro de Recursos Hídricos. p. 1-8.
Marotta, H., Santos, R.O., Enrich-Prast, A., 2008. Monitoramento limnológico: um instrumento para a conservação dos recursos hídricos no planejamento e na gestão urbano-ambientais. Ambiente & Sociedade, 11 (1), 67-79.
Michalak, A. M., 2016. Study role of climate change in extreme threats to water quality. Nature, 535 (7612), 349-352.
Moruzi, R.B., Reali, M. A. P., 2012. Oxidação remoção de ferro e manganês em águas para fins de abastecimento público. Revista de engenharia e Tecnologia, 4 (1), 29-43.
Neves, M. A. Fonseca, L. C.; L. C. B., Macedo; Alves, J. P. H., 2016, Qualidade da água do reservatório Jaime Umbelino – Barragem do poxim/Sergipe. Interfaces Científicas - Saúde e Ambiente, 5(1), 81 – 94.
Nilsson, C., Reidy, CA., Dynesius, M. Revenga, C., 2005. Fragmentation and flow regulation of the world's large river systems. Science, 308 (5720), 405-408.
Nordberg, G.F., Goyer, R.A. Clakson, T.W., 1985. Impact of effects of acid precipitation on toxicity of metals. Environmental Health Perspectives, 63:169-180.
Oliveira, A.B., Nascimento, C.W.A., 2006. Formas de manganês e ferro em solos de referência de Pernambuco. Revista brasileira de ciências do solo, 30, 99-110.
Oliveira, C.N., Medeiros, V.P., Pinto, Y.D., 2010. Avaliação e identificação de parâmetros importantes para a qualidade de corpos d'água no semiárido baiano. Estudo de caso: bacia hidrográfica do rio Salitre. Química Nova, 23 (5), 1059-1066.
Paerl, H.W., Paul, V.J., 2012. Climate change: links to global expansion of harmful cyanobacteria. Water Reserach. 46 (5), 1349-1363.
Queiroz, M.M.F., Dantas, E.F., Silva, A.L., 2013. Qualidade e quantidade da água do rio Piancó, tributário do rio Piranha-Açu na região Nordeste. Revista Verde de Agroecologia e Desenvolvimento Sustentável, 8 (2), 50-58.
Queiroz, M.M.F., Iost, C., Gomes, S.D., Boas, M.A. V., 2010. Influência do uso do solo na qualidade da água de uma microbacia hidrográfica rural. Revista Verde de Agroecologia e desenvolvimento sustentável, 5 (4), 200-210.
Rehana, S., Mujumdar, P. P., 2012. Climate change induced risk in water quality control problems. Journal of Hydrology, 444, 63-77.
Reiber, S.; Kukull, W., Standish-Lee, P., 1995. Drinking water aluminum and bioavailability. Journal of the American Water Works Association, 87:86-99.
Santos, S.M.S., Assis, J.M.O., Souza, W.M., 2014. Tendências de Mudanças Climáticas na Bacia do Rio Una, Pernambuco – Brasil. Revista Brasileira de Geografia Física, 7(2), 243-257.
Scarpinella, G,D., Miranda, R,B., Moccellin, J., Mauad, F,F., 2013. Produção de nitrogênio e fósforo totais provenientes da erosão em carreadores da cultura da cana de açúcar, Revista Recurso Hídrico, 34(1), 17-24.
Silva, D. F., Galvíncio, J.D., Almeida, H.R.R.C., 2010. Variabilidade da qualidade de água na bacia hidrográfica do Rio São Francisco e atividades antrópicas relacionadas. Qualitas Revista Eletrônica, 9(3), 1-17.
Silva, D.F., Sousa, F.A.S., Kayano, M.T., Galvíncio, J.D., 2009. Influência da variabilidade climática global e de suas escalas temporais sobre a precipitação no alto mundaú (PE). Revista Brasileira de Geografia Física, 2(3), 64-82.
Silva, I.F., Nóbrega, R.S., Galvíncio, J.D., 2009. Impacto das mudanças climáticas nas respostas

hidrológicas do rio Ipojuca (PE) – parte 2: cenários de aumento de temperatura. Revista Brasileira de Geografia Física. 2(2), 19-30.
Soares, V.M. Aspectos físicos e químicos do complexo de represas Paraibuna-Paraitinga, São Paulo. 2011.1-233f. Dissertação (Mestrado) - Instituto de Pesquisas Energética e Nucleares, Autarquia associada à Universidade de São Paulo. Universidade de São Paulo, São Paulo.
Valente, J.P.S, Padilha, P.M., Silva, A.M.M., 1997. Oxigênio dissolvido (OD), demanda bioquímica de oxigênio (DBO) e demanda química de oxigênio (DQO) como parâmetros de poluição no ribeirão Lavapés/Botucatu - SP. Ecletica Química. 22, 49-66.
Vasco, A.N., Britto, F.B., Pereira, A.P.S., Méllo Júnior, A.V., Garcia, C. A. B., Nogueira, L.C., 2011. Avaliação espacial e temporal da qualidade da água na sub-bacia do rio Poxim, Sergipe, Brasil. Revista Ambiente e Água, 6(1), 118-130.
Vidal, T.F.; Capelo Neto, J., 2011, Impacto da estratificação térmica na qualidade da água de reservatório do semiárido. Anais: XX Simpósio Brasileiro de Recursos Hídricos. p.1-8.
Wachholz, F. Influência da bacia hidrográfica e características espaço-temporais de variáveis limnológicas sobre reservatórios no Rio Jacuí – RS Rio Claro – São Paulo. 2011.1-196f.. Tese (Doutorado) - Instituto de Geociências e Ciências Exatas da Unesp. Universidade de São Paulo, São Paulo.
Zucco, E., Pinheiro, A., Soares, P.A., 2012 Deschamps, C.F., 2012. Qualidade das águas em uma bacia agrícola: subsídio para o programa de monitoramento. Revista de Estudos Ambientais, 14(3), 88-97.