Sustainable water management in the tropics and subtropics

and case studies in Brazil Vol. 3

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The publication aims to gather scientific production on water from Brazil and other parts of the world in a multidisciplinary way. Its common theme should make it a global book. The 53 articles of the first volume deal with Water and Agriculture. The 30 articles of the second volume address Water and its technologies. The 50 articles of the third volume show research on Water and Environment. The 63 articles of the fourth and final volume address Water Management.

Two years after its inception, the organizers now present this book, hoping that the four volumes will contribute significantly to the ongoing debate about water management.

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SUSTAINABLE USE OF WATER IN TROPICS AND SUBTROPICS: THE CASE OF APODI/MOSSORÓ RIVER BASIN IN THE BRAZILIAN SEMI-ARID

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INTRODUCTION

The water is one of the essential recourse of life, and even though it has been considered unsearchable, is known as the Petroleum of the XXI century, and it´s also a strategic fount of development of a country. It´s due to the fact, mainly, related to the way it´s distributed (around 1% of the portable water of the planet and as of user – easy access) the lack of a proper management use, and the contamination of water bodies hidrics and spring. The water crisis is one of a permanent threat, pointing in danger the survival of the humanity, imposing difficulties to the development, and increasing the water tendency diseases, by producing economic and social accruing the inequalities between regions and countries (TUNDISI, 2003)

Brazil occupies a prominent place among the richest countries in the world´s freshwater, with approximately 11.6% of total freshwater in the world. However 70% are located in the Amazon region and remaining 30% are distributed uneventually in the other regions, to supply 93% of the population. Among theses regions of Brazil,

the northeast has the lowest percentage of water resources and the second largest population, besides the predominance of semi-arid (MENDES, 2003).

In addition, the lack of sustainable planning in the process of the land use, intensified in Brazil from the 60´s led to the serious impacts on society as a whole, due to various environmental unbalance caused, such as contamination of water resources, it has been considered a strong threat to the national economy and public health. In general, the poor sanitation, the pollution of surface and under groundwater and the increasing demand for water indicates a strong tendency to ration this resources in the coming years (HUSSAR, 2008).

When it comes to laws, the country is covered with a law of high technical and social content, as the Law 9.433/1997 which establish the National Politic of Hydric Resources (BRASIL, 1997); the AGENDA 21, which is a program that has as its central issue the sustainable development, harmonizing environmental conservation, social justice and economic growth; and the Law 9.984/ 2000, which provides for the creation of the National Water Agency - ANA, whose mission is to regulate the use of waters of rivers and lakes of federal jurisdiction and to implement the national water resources management, insure good quality water in sufficient quantity for the current and future generations (BRASIL, 2000).

Even though having all this legal foundation it has not prevented water bodies undergo changes in the environment, jeopardizing the quality of its waters.

The Apodi/Mossoró river basin, located in the state of Rio Grande do Norte (RN), semi-arid region of northeastern Brazil, is a typical example of this problem. This water resource is under constant impacts from leaching of fertilizers and pesticides used in the areas of agricultural activities developed in the surroundings, the constant discharge of domestic and industrial sewer in

its waters, the removal of riparian vegetation and the inadequacy of the solutions used for to garbage.

Recent research indicates that the water of the Apodi/Mossoró river is in an accelerated process of eutrophication (MARTINS et al., 2008a; MARTINS et al., 2008b; OLIVEIRA et al., 2009) and considerable concentrations of metals were found in the Dam of Lucrécia, a reservoir belonging to this basin, and their water of the possible causes of the high incidence of cancer mortality in the region (ZARA et al., 2006).

These results are in agreement with the observed spot, verified by the presence of aquatic macrophytes (water hyacinth), smelly and green and oozy. This problem becomes even worse by the fact that river to be temporary arrangements, and a drastic reduction in its flow from the month of June, becoming practically zero between the months of November and December, when it can be observed "green carpet" made of water hyacinth on the surface of the river water.

The recovery of the river, in other words, its return to its healthy desire is cherished by the people he sees, that the economic potential, the landscaped area and leisure, employment generation and income for coastal communities and a better health condition public. Therefore, it is necessary to adopt measures of recovery and management to promote their capacity for self-sustaining.

Thus, considering the need to know, in an integrated way, the weaknesses and potential of the river, allowing a better mark for the deployment of services and works necessary in the interests of urban and rural development, a team of researchers from different disciplines (chemistry, biology, agronomy, among others) met to develop the project "Rio Apodi/Mossoró: Integridade Ambiental a Serviço de todos", from which we obtained the diagnosis of environmental change in Apodi/Mossoró river

hydrographic basin, identifying likely environmental contamination and its sources of risk to human health.

DESCRIPTION OF THE STUDY AREA
THE STATE OF RIO GRANDE DO NORTE

The state of Rio Grande do Norte, located in northeastern Brazil, has a territorial extension of 53,077 Km^2 and 410 Km of coastline, which is concentrated more than half of its population, which is 2,776,782 inhabitants, according to census population of the Brazilian Institute of Geography and Statistics (IBGE) in 2000.

The variation in the climate is arid (central and north coast) to humid (east coast) determining the occurrence of vegetation varied as Caatinga (predominant), Mata Atlantica, Restinga Forest, audio and mangrove forests.

Although the state has a large portion of its territory located in semi-arid, with 5.4% for desert areas and 57.4% in categories severe and very severe desertification, has significant areas for irrigated cultivation, and be responsible for 90% of the production of salt in the country and occupy the second position in the production of petroleum. It is also an important tourist attraction and natural gas, textiles, tropical fruits, sugar, fish productions and, more recently, shrimp in captivity (IDEMA, 2002).

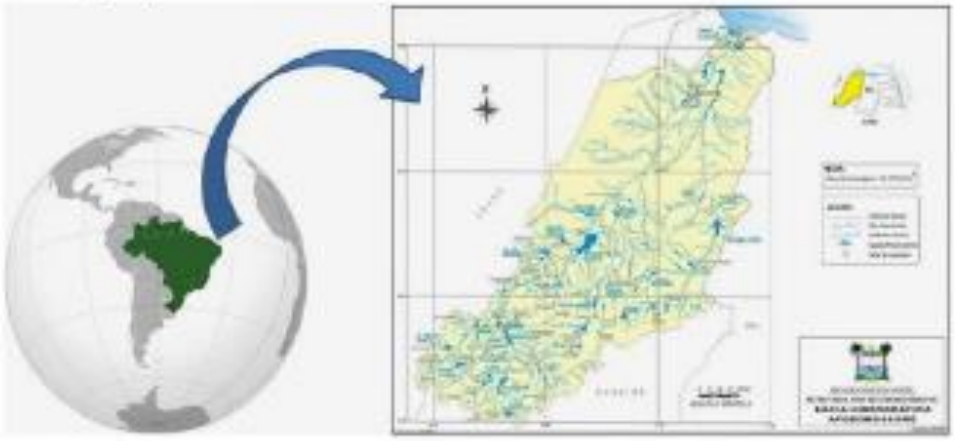
With respect to water resources, the state has 16 hydrographic basins. In the domain of semi-arid is one of the largest: the Apodi/Mossoró river basin. In this basin the crystalline terrains are waterproof and cause rain to become quickly in superficial running, thereby contributing to the burst of the rivers.

THE APODI/MOSSORÓ RIVER BASIN
HYDROGRAPHY

The Apodi/Mossoró river basin (Figure 1) is located in the western state of Rio Grande do Norte and has an area of 14,276 Km^2, representing 26.8% of the territorial State, and are one of the most important the region. Are

618 registered dams, a total volume of 469,714,600 m³ of water, representing 27.4% and 10.7% of total dams and accumulated volumes of the state, respectively. Its main river has a course of 210 Km long, rises in the mountains near Luis Gomes, border with the state of Paraiba, and has its mouth-shaped estuary, home to a significant coastal plain between the towns of Areia Branca and Grossos.

Figure 1 - Location map of the Apodi/Mossoró river basin, RN, Brazil. Source: Institute for Sustainable Development and Environment - IDEMA, RN, Brazil.



In the course of the Apodi/Mossoró river are some of the main reservoirs for water supply in the state, highlighting the following: Dam Pau dos Ferros (Figure 2A), completed in 1967 by the National Department of Works Against Droughts - DNOCS, with a capacity of 54,846,000 m³. Its water is used mainly for the development of irrigation schemes and for human supply; Dam of Santa Cruz (Figure 2B), which opened in March 2002 with a capacity of 560,000,000 m³, and is used so far for the small-scale aquaculture and perpetuating the river to its users.

Passing through the city of Mossoró, largest urban center in the region, the river has its interventions in the natural course for the construction of two canals (Figure 3). A smaller channel, called Channel Tricotomização, and

a larger one, called Channel Dix-Huit Rosado. In addition to these diversion channels were constructed four successive dams that control water flow during the year, which are: Genésio dam, dam of the Center, Barrocas dam and Passagem de Pedras dam. The two diversion channels, along with the four dams, form a system of flood control Apodi/Mossoró river, important to minimize flooding in the city during the rainy season.

Figure 2 - Pictures of the levees Pau dos Ferros (A) and Santa Cruz (B), in the Apodi/Mossoró river basin, RN, Brazil.

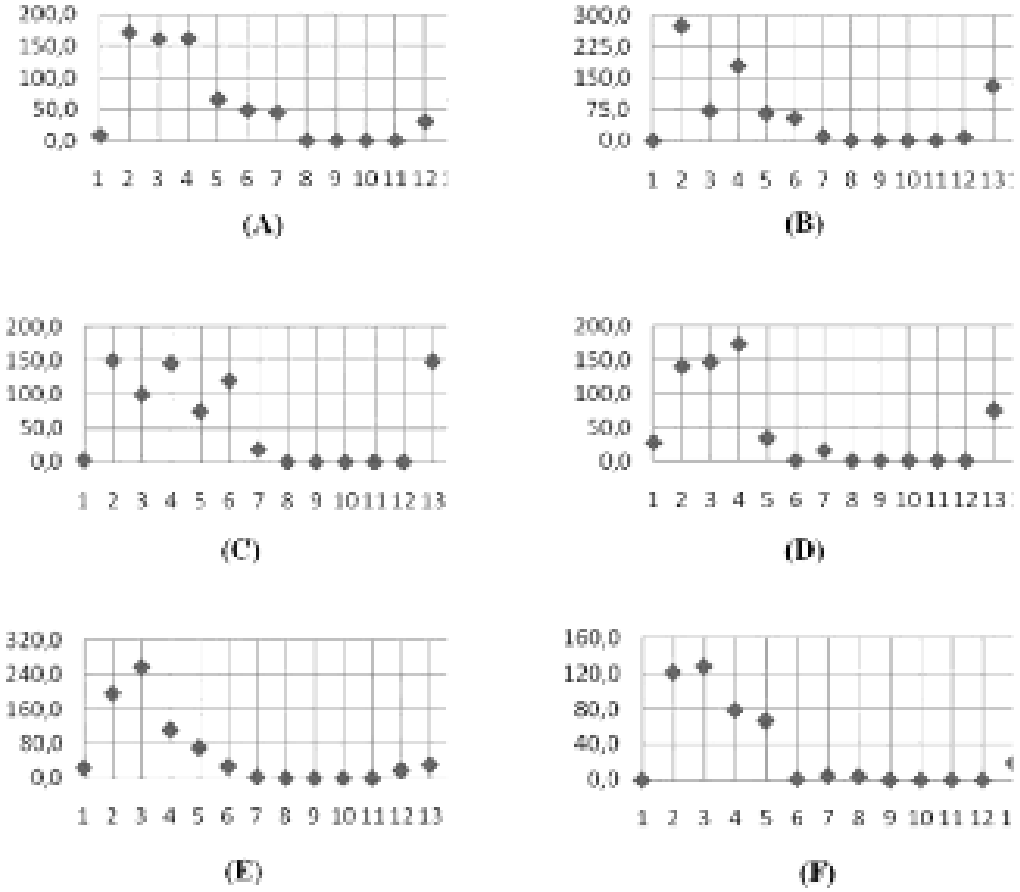
A B

Figure 3 - Aerial view of the main river bed and channel Dix-Huit Rosado and Tricotomização in the Apodi/Mossoró river, RN, Brazil.

CLIMATE

The prevailing mood in 80% of the Apodi/Mossoró river basin, second Thornthwaite, is semi-arid and according Köeppen is dry and very hot, like BSWh, with two well defined seasons: the dry season usually goes from June to January, and a rainy season from February to May (CARMO FILHO et al., 1991). In mountainous areas of the basin, 20% of the area, near the springs, the type occurring AW, characterized by a tropical rainy climate with dry summer and rainy season in the fall.

Figure 4 - Indices rainfall in the cities of Luis Gomes (A), Pau dos Ferros (B), Apodi (C), Governados Dix-Sept Rosado (D), Mossoró (E) and Areia Branca (F), in the period of 2007/January to February/2008. Source: National Institute of Meteorology - INMET.



The rainfall average for the low basin is between 600 and 800 mm and the average for the upper basin are between 800 and 1100 mm. From August the precipitation decreased significantly, and in October and November practically nonexistent (Figure 4) and second AB'SABER (2003), the direct effects of the heat is experienced in the regional economy due to the lack of continuity of rivers and water in the soil, which prevents the production of any culture other than through the irrigation and the production of fish disappears, taking the man who lives in this region, often having to migrate to other places.

GEOMORPHOLOGY

From the geomorphologic point of view, the Folk Depression is the unit more representative, especially in the southern portion of the basin, characterized by much dissected terrain in the form of mountains and high ridges. Over the medium-haul and part of the lower course of the Apodi/Mossoró river, the unit representative is the Chapada do Apodi, predominantly flat land to gently rolling. In the northern portion, corresponding to the lower reaches and estuarine area, dominated by fluvial-marine plains, resulting from the accumulation of sediments from rivers and sea, characterized by flat land.

VEGETATION

In relation to the occurrence of vegetation, due to the semi-arid climate, the proeminent vegetation is "Caatinga", whose classification which is related to the change in his countenance, arising from the main interaction of soil and climate, as well as anthropogenic interference. According to ANDRADE (1981), the vegetation is classified into forest and non forest, recognizing the latter case, herbaceous and woody vegetation and purely herbal. In relation to forest vegetation, including within the Caatinga vegetation of shrubland.

ECONOMY

The role of the river stands out as important imponderable at the various stages of economic development for which has passed the region bathed by it. Currently, a holding very important to the economy of the region is irrigated fruit, melon which is the main product of this fruit culture. In 2004, exports of this fruit totaled more than $ 45 million. Remarkable, too, papaya, banana, mango and watermelon (IBGE, 2006). Moreover, they are found, usually low water crops, planting potatoes, corn, etc. The region stands out, too, as the largest producer of shrimp from Brazil, according to the conditions for the establishment of shrimp in captivity. The Rio Grande do Norte State accounts for 41.5% of national production, with 40% of the producing farms are located in areas of the mouth (estuary and mangrove).

Another relevant activity is the salt industry, also located at the mouth of the Apodi/Mossoró river. The state accounts for about 90% of the Brazilian sea salt (DNPM, 2006).

The State is also the largest petroleum producer in the country's land, being more concentrated in the medium and lower reaches of the Apodi/Mossoró river. The petroleum sector is one of the most important for the region.

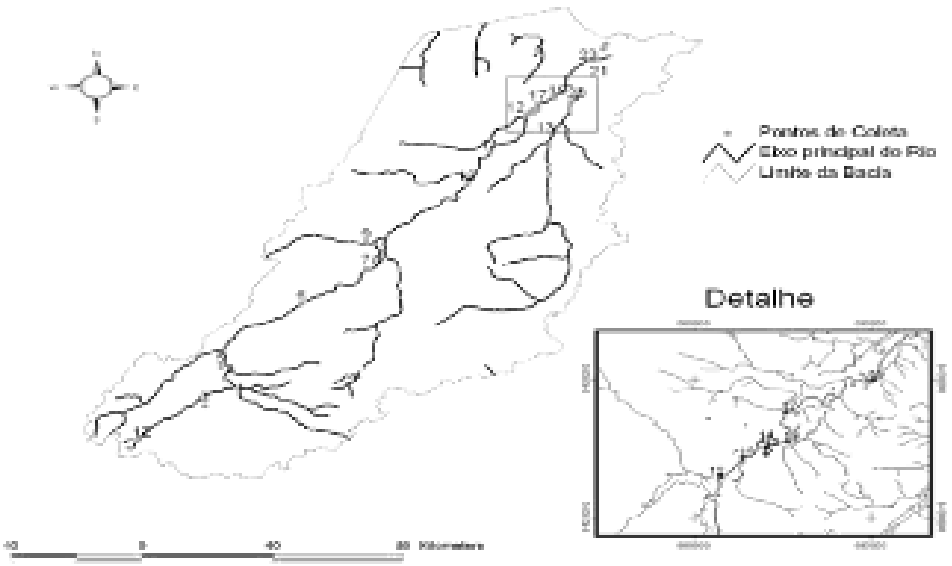
POPULATION

The Apodi/Mossoró river basin involves 51 municipalities and a population of about 602,843 inhabitants (IBGE, 2000). The main towns that are cut by the riverbed Apodi/Mossoró comprise a population of about 333.229 million inhabitants, representing 12% of the state population, with the highest concentration is in the municipalities of Mossoró, Apodi and Pau dos Ferros. However, less than 20% of the population has sewerage connections active.

METHODOLOGY

For the selection of the sampling points of environmental samples was considered the possible occurrence of human impacts, such as practices and the inappropriate use of land for farming, salt plants, shrimp farming and urbanization, the occurrence of different types of plants indicative of water pollution and the existence of the preserved, to be compared with the impacted sections. Were marked 24 sampling points distributed along the hydrographic basin from the source to the mouth, which are represented in Figure 5 and described in Table 1. Samples were collected quarterly from August/2007 to October/2008, having been held three collections during the rainy season and three in the dry season. We collected samples of water, bottom sediment, aquatic plants (Eichhornia crassipes, commonly known as water hyacinth), the soil around the river and effluents commonly discarded in it.

Figure 5 - Map of Apodi/Mossoró river basin, with the location of sampling points.



The samples were properly packed in suitable containers, properly labeled, stored under parameters to

be analyzed and stored in coolers with ice, to be transferred to the laboratory. Additionally, we recorded the geographic coordinates and all information relevant and important (Table 1), such as the presence of animal feces and plantations in the margins, presence of plants, color and odor of water, etc.. Once in the laboratory, samples were immediately analyzed or properly prepared and stored, where the parameters to be analyzed so allow for further analysis. The processes of collecting, processing of samples and analysis were performed, always in triplicate, according to standard methodologies available in literature (APHA, 1998 and EMBRAPA, 1997).

Table 1 - Description of the sampling points of environmental samples in the Apodi/Mossoró river basin, RN, Brazil.

Point	Coordinate Location		Description of the sampling points
	S	W	
P1	6°22'8.00"	38°27'22.60"	Region of springs (Luis Gomes). LP [1,2,3,4]
P2	6°22'11.00"	38°26'6.00"	Region of springs (Luis Gomes). BP [1,4,6,7,14]
P3	6°14'50.00"	38°16'54.00"	Rafael Fernandes. LP [1,2,3,4,13]
P4	6° 8'50.00"	38°11'35.00"	Dam of Pau dos Ferros. LP, BG [1,3,11,14]
P5	06° 00' 25.4"	38° 12' 13.8"	Central Region of Pau dos Ferros. LP [1,3,7,14]
P6	05° 55' 04.3"	37° 58' 50.4"	Bridge that connects Umarizal to Itaú. A [1,3,4,7,9,10]
P7	05° 49' 38.4"	37° 48' 07.9"	Santa Cruz dam (Apodi). LP, BG [1,4,13,14]
P8	5°45'52.12"	37°47'41.47"	Downstream of Santa Cruz dam (Apodi). LP [1,3,12,14]
P9	05° 40' 05.8"	37° 47' 35.0"	Apodi Lake. L. (1,4,5, 6,7,8,9 e 12)
P10	05° 27' 40.6"	37° 31' 23.3"	Governador Dix-Sept Rosado. LP [1,4,5,7,10,11,12,13]
P11	05° 26' 09.3"	37° 30' 51.9"	Exit of Governador Dix-Sept Rosado. LP [1,4,5,7,8,9,11]
P12	05° 13' 08.1"	37° 21' 45.4"	Gonçalo dam (Mossoró). LP, BP [1,4,5,7,10,12,13]
P13	5°12'22.84"	37°20'1.84"	Bridge of the Railroad. LP [1,4,5,6,8,10,11]
P14	5°12'16.81"	37°20'22.60"	A. de S. Manoel (Mossoró). BP, CDH. [1,4,5,6,8,10,11]
P15	05° 12' 10.0"	37° 20' 13.5"	Flávio's Restaurante (Mossoró). CDH. [1,4,5,6,8,9,11,14]
P16	05° 11' 59.0"	37° 20' 10.8"	Bridge from Houda (Mossoró). CT. [1,4,5,6,8,12,13]
P17	05° 11' 41.1"	37° 20' 25.3"	Oco school dam (Mossoró). LP, BP [1,4,5,6,7,9,10,11,12,13]
P18	05° 11' 43.6"	37° 19' 44.2"	Ponte 1 Leste-Oeste (Mossoró). LP. [1,4,5,6,8,9,11,13]
P19	05° 10' 36.1"	37° 19' 48.7"	Barreras dam (Mossoró). LP, BP [1,4,5,6,7,8,12,13]
P20	05° 09' 21.0"	37° 17' 09.2"	Passagem de Pedras dam (Mossoró). LP,BP [1,4,5,6,7,8,9,10,11,12,13]
P21	05° 10' 09.3"	37° 14' 10.8"	Bridge of Carnaubinha River. A [1,4,5,7,12,13]
P22	5° 7'56.07"	37°16'5.37"	Shrimp in captivity Downstream (Geonasa). LP [1,4,5,7,8,12,13,14]
P23	04° 58' 48.8"	37° 08' 54.9"	Port of Geonasa. LP [1,4,5,7,8,12,13,14]
P24	04° 57' 20.1"	37° 08' 11.8"	Port of Areia Branca. LP [1,4,5,7,8,12,13,14]

LP = main bed, A = affluent, CT = channel tricotomização, HRC = channel Dix Huit Rosado, L = lagoon, BG = big dam, BP = small dam, [1] = place without water during the dry, [2] = mountainous region, [3] = presence of stool, [4] = watering place, [5] = plantations on the banks, [6] = presence of aquatic plants (water hyacinth, [7] = set of bath and fishing, [8] = presence of wastewater, [9] = water used for human consumption, [10] = bed on limestone, [11] = presence of irrigated agriculture in the area, [12] = presence of organic matter, [13] = bad smell, [14] = presence of boats, [15] = point of car washes.

The results were, when possible, compared with the Brazilian law to obtain a default on the quality of river. In some cases where there is no parameters in national legislation, other standards were used for comparison, as the EPA and CETESB. Taxonomic identifications were made by comparison with the literature and by experts from herbaria (Universidade Federal do Rio Grande do Sul, Universidade Estadual de Campinas and Universidade Estadual Paulista). The classification system used was that of Cronquist (1981) to Magnoliophyta (Angiosperms), the dictionary Willis (1973) for Pteridophyta; Crandall-Stotler (1980) for Hepatophyta and Cook (1974) for families of aquatic monocots and dicots. The ecological types were established according to ESTEVES (1998).

RESULTS AND DISCUSSION

Water quality depends on the nature of where it is and waste in it that is discarded. Depending on its quality, the water may have different uses. However, their irrational use brings many consequences to humans, caused mainly by changes in their physical, chemical and biological characteristics.

The intake of substances in water sources comes from several sources, each with its own characteristics on the quality and quantity of pollutants they carry. Due to the different species contributed becomes practically impossible for systematic determination of all pollutants that may be present in water. Thus, in this study were selected some physical, chemical and microbiological parameters representative to indicate the water quality of Apodi/Mossoró river basin. In total, there were more than 12,000 analyses during the two years of the project, thus preventing the presentation and detailed discussion of all of them in this work.

Overall, the results showed different performances in the following locations:

1-Those who receive discharges of domestic and industrial wastewater in nature in the river, a fact noticeable close to major urban centers of the basin (Pau dos Ferros, Apodi and Mossoró);

2-Those who are not part of the natural bed of the river (lake, ponds, tributaries and diversions);

3-Those that have some intrinsic feature local or any impact by the existence of some economic exploitation.

Relating to seasonality, it is noteworthy that all parameters are strongly influenced by the same, increasing or decreasing in the rainy season in accordance with the environmental factors that influence them. For several parameters, the results were much lower in the rainy season than in the dry season. For others, however, the reverse was observed, in other words, an increase in the concentrations of the substances analyzed.

During the rainy season normally expect to find lower concentrations of the variables, due to the dilution effect. However, due to the accumulation of pollutants washed away from the vicinity of the river to its bed, the level found may be higher; the greater movement of water during the rainy season can make, for example, that elements that are adsorbed in bottom sediments are available for the water column, increasing their level the same; besides that, the results show a strong influence of local characteristic and activities practiced in their surroundings.

In the city of Pau dos Ferros the water from the dam (Point P4) showed good quality. The results were incresely significant only in samples collected in August and November 2007 and for the parameters turbidity and biochemical oxygen demand (BOD). After the rains that occurred in 2008 were significantly reduced. Moreover, in the central region of Pau dos Ferros (Point P5) the river is a bad water quality. The results were higher for parameters

turbidity, nitrate, BOD, chemical oxygen demand (COD) and fecal coliform bacteria, and very low to the dissolved oxygen (OD). These data are indicators of the presence of wastewater without any treatment and feces of warm-blooded animals. The water quality should be the result of the constant discharge of wastewater from the urban center that is directly into the body of water and animals that are freely established on its banks. It should be noted that this location the amount of wastewater gets to be greater than the natural flow of water from the river during the dry period.

For the city of Apodi, the Point P7 differs from the others, showing the action of the dam of Santa Cruz, which stops the river flow, allowing the sedimentation of salts and consequently decrease its quantity in the water. Thus, except for total phosphorus and barium, which showed high concentrations in water, the other parameters measured had low concentrations, explained by the dilution process, due to the large volume of water. In Point P8 (downstream of the dam), with the exception of the phosphorus concentration was high, the others were low. In this case, it is considered that water released by dam, besides diluted is favored by high oxygen, because the flow of water is much higher. As for Point P9, located in Apodi Lake, the results were very worrying, the water quality is bad. The results of phosphorus, BOD, COD and barium in water, for example, were high and the DO concentration was low. According to observations made on the spot, in addition to disposal of domestic wastewater in the lagoon, the region is characterized by the presence of agricultural activities. On the other hand, one should consider that the soil around the river also had high concentrations of barium, so the values obtained in water may be due, including the actual geology of the region.

The urban area of Mossoró is also very negatively impacted, with bad water quality, especially the points P14, P15 and P16 which are located in canals (out of the

natural bed of the river). We obtained high levels of dissolved total solids (DTS), chloride, total phosphorus, nitrate, BOD, COD and fecal coliform, and low OD. These results are in agreement with the observed spot: the water is green and oozy and there is lots of water hyacinth. This may be the result of the large discharge of domestic wastewater in water. Moreover, normally found feces on the river due to the presence of animals. For channels of diversion, the complicating factor is that they are, in most of the year, interrupted by grounding, which prevents the renewal of the water.

Importantly, the large amount of nitrate and total phosphorus in a body of water increases the eutrophication process. The points where the concentrations of these compounds were high, was also observed an abundance of floating aquatic macrophytes, especially Eichhornia crassipes (water hyacinth). This species has a high growth rate when in environments with large amounts of nutrients and can form monospecific banks completely blocking the whole channel of an ecosystem (CAMARGO et al, 2003), as well as occur in some spot of the Apodi / Mossoró river.

Another area that deserves attention is the estuary, which showed significant results, for example, the concentrations of nitrate, COD and barium. This fact, initially, can be thought of as being due to the natural condition of the region, which is influenced by tides, increasing the concentration of some compounds, besides the local geology. On the other hand, one should consider that the concentration of nitrate, for example, is high for saline water. Note that all collections of samples were carried out during low tide. Thus, the results are indicative that there may be contributions from domestic and industrial wastewater are disposed in the River.

It should be noted also that the samples collected from the region of Pau dos Ferros, Apodi, Mossoró and estuary, usually presented COD/BOD ratio high, indicating pollution due to the presence of non-biodegradable

material, or which might remain in body of water for considerably long time. In this respect, calls attention to the presence of fecal coliform, which indicates the possibility of pathogenic microorganisms responsible for the transmission of waterborne diseases.

On the analysis of effluent produced in the region, in Pau dos Ferros analyzed samples of domestic sewer and slaughterhouse cattle; in Apodi the samples from domestic sewer and poultry slaughterhouse; in Mossoró the samples of domestic sewer and waste stabilization ponds; and in the estuary, the samples of wastewater from the salt production and shrimp effluents. All effluents had concentrations above the parameters analyzed in samples of river water, in other words, the results show that, for example, all effluents contribute to the high concentration of total phosphorus present in the river and, therefore, with its eutrophication; when it comes to the COD, the highlights were the effluent from the slaughterhouse in Pau dos Ferros, and the salt and shrimp in the region of the estuary. Concentrations of fecal coliform in the effluent were also very high, with the exception of wastewater production of salt and shrimp. Finally, these results are indicative that all of these effluents are potential sources of pollution to the waters of the Apodi / Mossoró river basin.

However, one should consider that some elements had high concentrations in the soils of the region, while small concentrations present in effluent samples, indicating also the influence of soil in the levels of some parameters found in water.

The metals Mn and Ba must come from both the effluent and the soil itself, ie, these metals are being washed away from soil to water by leaching or presented to the water through the sediment. It is worth mentioning that these metals may be due to the very local geology, but also may come from agricultural activities carried out in the river environment. Moreover, the metals Ni and Pb

were not found in significant concentrations in the soil around the river, or sediment, but were found in water, suggesting that they have as a source of effluent.

Whereas the quality of a body of water should be considered in an integrated form, the pollution of the river was also assessed by analyzing the physicochemical and biological properties of sediments and plants.

The Sediments, besides providing habitat for many aquatic organisms, act as complex reservoirs of inorganic substances, organic matter and adsorbed and dissolved constituents. Most of the decomposition occurs in the sediments. Thus, the physical and chemical characterization of sediments on the grain size profile and the concentration of metals are of great importance for the understanding of natural and anthropogenic processes that occur in these systems.

The distribution of nutrients and contaminants in a water body occurs predominantly on the surface of particles of solid phase, in other words, the suspended particles, in deposition or pending at the bottom of the aquatic environment (SIGG, 1985; MOZETO, 2004; MOZETO et al., 2003; SILVÉRIO et al., 2005). This effect is more pronounced the finer the particles. Thus, in a discussion of sediment contamination by chemicals the fractions most important are the clay and silt, which presented higher potential for adsorption of metals. According to MOZETO et al. (2006), the fractions of fine-grained sediments (< 62 ìm) make up the largest part of the adsorption of contaminants. In the fractions above 62 ìm, which is considered essentially sand, there is a linear decrease in metal content (WETZEL, 1983).

The size of the sediments of the river presented a coarser texture near the source of the river and as you approach the mouth becomes thinner, with the highest percentages of fine sand and some samples of silty texture. Since the sediments of the river showed no

significant values for the clay content, this indicates the development of very low level of clay soil in its sorroundings. This result is important for monitoring water quality, since the soil on its banks, it is more sandy, can lead to an increased mobility of toxic chemicals to their water. Moreover, during the rainy season there is a tendency for greater amounts of coarse sediments, which reveals a condition of degradation of margins, indicating that the river is being silted-intensive. The increased mobility of elements for water and heavy siltation are favored by the absence of riparian vegetation.

The concentrations of metals in sediments, the values were generally much higher than those of water. The highest concentrations were obtained in the region of the estuary. However, the points located at the exit of Governador Dix-Sept Rosado, in the urban area of Mossoró, in the Apodi lake and in central Pau dos Ferros also showed considerable concentrations.

For metals, as found in water and river sediment, plants may also have levels of metals. It was observed that plants assimilate all the metals, both the leaves and roots. It is worth noting that these aquatic plants play different roles, among them, the release of nutrients through the so-called effect of "pumping", which is the absorption of nutrients from the sediment and its subsequent release into the water column by excretion or during their decomposition and the role bioindicator of water quality.

Only certain metals are essential to plant growth to complete its life cycle. According to LARCHER (2000), the absorption of metal by the cells, particularly the roots, is facilitated by the mechanisms to transport and accumulation, because many metals are really necessary to plants as micronutrients, however, the plan cannot prevent the entry of toxic elements by the same mechanisms. However, the results showed significant variations, suggesting that the difference in residence

time of the plants and the possible migration of the same in the course of the river, impact significantly.

Besides the studies of grain size and metals in sediments, also important is the biomonitoring. The Benthic macroinvertebrates have been used in the monitoring of water bodies at different levels of human impact. When these organisms are subjected to adverse conditions, some groups resist or die. Therefore, the species composition and spatial-temporal distribution of aquatic organisms are altered by the action of the impacts. The more intense they are, the more pronounced will be the ecological responses of aquatic bio-indicators of water quality, and there may even local extinction, or exclusion of sensitive organisms to pollution.

The analysis showed that near the source and the region of Governor Dix Sept Rosado we observed the greatest number of individuals susceptible to organic enrichment, showing that these are places with lower levels of pollution throughout the basin. In the other points were found only bodies that are resistant to pollution, indicating that these environments, at the time of collection, showed high levels of pollution. It was also observed in all points, low species richness, indicating that the environment does not present conditions for the development of organisms sensitive to organic enrichment. These results are consistent with the results of physical and chemical.

Regarding the fauna of molluscs, it was observed, including the presence of Biomphalaria straminea, planorbid that acts as intermediate host of Schistossoma mansoni, which is responsible for schistosomiasis ("water belly").

Furthermore, we observed the presence of Thiarid melanoides in almost all sampling points. This organism is exotic and their introduction is relatively recent, and good colonizing and occupying a prominent place in number of organisms collected.

Still using plants as bioindicators of water quality was also performed the analysis of benthic macroinvertebrates in the water hyacinth. The results showed that in Pau dos Ferros and Mossoró, where samples were collected from water hyacinth, there are more tolerant organisms, indicating the existence of organic enrichment and, consequently, poor water quality.

Additionally, we performed the identification of aquatic plants found in the Apodi/Mossoró river basin. The free-floating species were more abundant Pistia stratiotes and Eichhornia crassipes, pollution indicator of a body of water and showing the process of eutrophication. These two species of aquatic macrophytes occur mainly in Mossoró. All other species, except for Ruppia maritime and emerged, it hadn't occurred in the estuary, possibly because of lack of tolerance to salinity present in these points.

The submerged species and rooted with floating leaves showed reduced occurrence in the Apodi/Mossoró river, which agrees with the fact that mainly occur in more oligotrophic environments and in water with low turbidity.

Considering the analysis of the soil around the river, there were significant concentrations of phosphorus, which are not normal for the soils of the region. Despite being a powerful nutrient, such high levels can even cause toxicity to plants in the soil, plus the ability to be leached into the body of water, causing eutrophication of the environment.

In mean while the soil microbial biomass, considered to be a living part of soil organic matter, showed low values. Whereas this works in microbial carbon cycling of soil nutrients, the ciliar banks of the Apodi/Mossoró river present problems as the degradation. Items that showed the highest values were those where there is disposal of effluents, since the sewers concentration of organic matter is high. However, it should be noted that the sewers are also toxic compounds.

CONCLUSIONS

All studies indicate a critical state of water quality of Apodi/Mossoró river basin, especially in the urban centers of Pau dos Ferros and Mossoró, Apodi Lake and region of the estuary, where the situation is more severe dry season. The possible reasons are deforestation, agricultural activities and livestock performed poorly, and the release of domestic and industrial effluents without a preview treatment.

However, to better understand the behavior of various compounds discussed here and therefore the degradation of which is in this aquatic system, it is necessary to study longer and more complete with insert, for example, analysis of compounds organic.

It is worth noting that one of the consequences of pollution is the risk of disease. In addition, a future not far from the population may need this surface water for human consumption, since the water used today mostly come from the groundwater and the withdrawal may be in more than a replacement.

Thus, it is necessary immediate action to reduce the environmental degradation of Apodi/Mossoró river. Suggestions for better recovery and use are to treat domestic and industrial effluents before disposal in the river bed, preserve and restore riparian vegetation, developing practices of environmental education to increase awareness of the people, to do the monitoring work for the due performance legislation, creating a river basin committee involving representatives from all municipalities in the basin, and exploiting their natural resources, to promote the development of the region and enhance the health and quality of life of the population. The restoration work of this aquatic ecosystem is long, expensive, complex and depends on active and integrated throughout the company. As soon as the actions are implemented to prevent their pollution, the greater the chance of success.

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