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Pitimbu River Lowland Portion Water and Sediment Monitoring Data, Natal Brazil

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Abstract: Urbanization in developing countries has had a significant impact on water resources and the environment. Anthropogenic-related factors such as deforestation, uncontrolled urban occupation and the lack of sustainable measures have affected both the quantity and quality of water. The Pitimbu river watershed (126.7 km^2) is located within the urban area of Natal, Brazil. The effects of urban occupation have recently been a concern to municipal authorities, since the Pitimbu is the main source of domestic water supply. In this paper authors analyze monitoring data, including the quantitative and qualitative water and sediment factors at the lowland portion of this river system. To this end, two transverse cross sections were established, 5.6 km apart. The monitoring survey included measurement of water discharge and biological sediment analysis over a period of 11 months (Nov 2007 to Oct 2008). Water discharge varied from 0.62 m^{3}s^{-1} (dry season) to 10.61 m^{3}s^{-1} (rainy season). Discharge rates were used to fit Depuit-Boussinesq baseflow recession equation parameters. The recession constant (0.8) revealed strong river aquifer interaction. Such interaction explains the increase in discharge between the two sections by a factor of 1.98. Increasing sediment input to the river channel has occurred during high magnitude events, resulting in channel sedimentation. Biological sediment analysis revealed both the absence of sensitive benthic species (Corduliidae) and abundance of resistant benthic species (M. Tuberculata), indicating the occurrence of heavy metal contamination.

***Keywords**:* Pitimbu; water quality; monitoring; benthic

1. INTRODUCTION

In Brazil, the growth of urban areas has produced the human settlement of environmentally protected areas, causing impacts on water resources and the environment. In this context, social, commercial and institutional factors interact jointly to aggravate the problem, transforming it into a priority from the sustainability viewpoint. In contrast, the increasing water demands in urban zones highlight the importance of adopting policies in order to control occupation in the basin area.

In the metropolitan region of Natal, the hydrographic basin of the Pitimbu River (BHRP) is strategically important. Water captured directly in the river channel supplies around 30% of the population, with a flow rate 0.722 m^{3}s^{-1}. On the other hand, the pattern of basin area occupancy has increased potential risks of ecosystem and water quality degradation. Since the 1970s the local water company has used an extensive network of deep wells for local supply. In recent years, the increase in nitrate levels in ground water has caused an increase in demand for Pitimbu River surface water, which is used for improving drinking water quality.

Earlier studies associated the process of land occupancy in the BHRP to a series of negative effects in the water and in the ecosystem, caused mainly by the precariousness of the sewage system and the increase in occupancy density [Borges, 2002; Santos *et al*., 2002; Araújo *et al*., 2007; Ferreira and Silva, 2009].

The BHRP has a drainage area of 126.76 km² (Figure 1), spanning three municipalities in the metropolitan region of Natal: Macaíba (47%), Parnamirim (43%) and Natal (10%). In recent years, the environmental challenge and signs of degradation have sensitized sectors of society to the urgency and seriousness of a problem that affects the entire population.

This study has the following aims: a) to assess the quality of the aquatic ecosystem using biomonitoring; b) to adjust the parameters of the Depuit-Boussinesq equation using water discharge data during the dry season. This equation is used to represent recession water discharge behavior [Hall, 1968]; c) to assess recharge characteristics along a lowland stretch in the urban zone. To this end, two transverse cross sections were established: section 1(BR-101) and section 2(EMPARN), extending 5.69 km. Monitoring took place in both the dry and rainy seasons, over a period of 330 days (November 2007 to October 2008).

2. STUDY AREA

The BHRP lies over sedimentary rocks that form the Barreiras group. The region also contains movable dunes, paleodunes and Quaterrnary sand deposits. Hydrologic soil properties show their high infiltration capacity. Rainwater infiltrates rapidly into the soil, promoting storage and underwater flow through the non-confined aquifer.

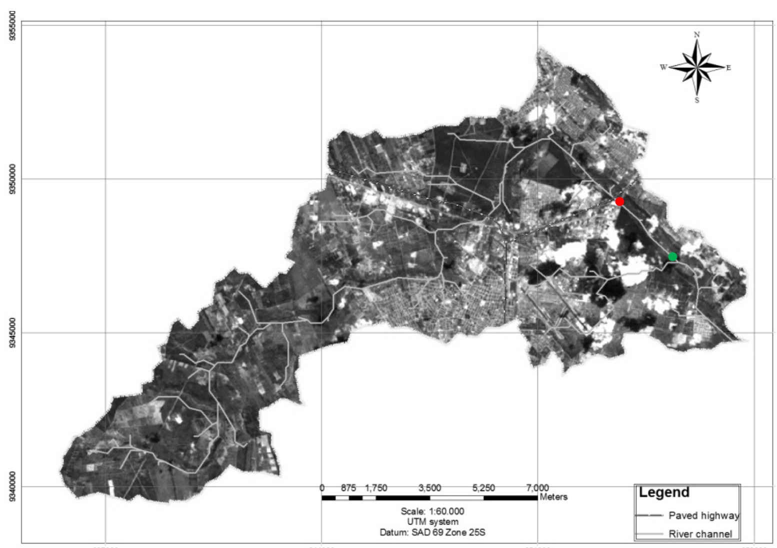

Figure 1. Pitimbu river watershed. Source: LANDSAT on 11-10-2007.
Transverse Cross Sections: • 1 (BR101) • 2 (EMPARN)

In 2002 the BHRP contained areas of native vegetation, located in preserved military zones. In 2009, most of the basin is covered with anthropized vegetation and to a lesser extent areas of agriculture and urban occupancy. However, the occupied areas occur near the protected zone of the river, causing degradation of both the ecosystem and water quality. Furthermore, the area of the basin not yet influenced by anthropogenic activity (13%) shows the intensity of land occupancy and use [Borges, 2002; Santos *et al*., 2002].

In the process of BHRP occupancy, degradation is associated to diffuse pollution from different origins: a) domestic and industrial wastes; b) residential septic tanks; c) toxic substances (pesticides) used in agriculture; d) human settlement areas reduce infiltration and increase surface runoff, generating erosive processes and silting in the river channel. During maximum water level events the transport of organic substances from lateral banks was observed, associated to settlement areas near the main channel. Indeed, the advancing urbanization toward natural floodplains has caused damage to the ecosystem, thereby compromising water quality. In this sense, the failure to implement an effective program to control the occupancy of these areas has put the sustainability of the ecosystem and water quality at risk, which may soon preclude the latter's use for human consumption.

2.1 Biomonitoring

Biomonitoring can be defined as the systematic use of organism responses aimed at assessing environmental changes, generally caused by anthropic action [Buss *et al*, 2003]. The results obtained in biomonitoring reflect the wide array of situations that water bodies are subjected to, given that biodiversity and faunal characteristics are the result of pressures exerted on the ecosystem.

Benthic macroinvertebrates, used in the formulation of biotic indices, are considered good indicators of environmental pollution in lotic systems. It is believed that these organisms respond to hydraulic, organic and toxic stresses, leading to a reduction in sensitive species and proliferation of resistant and tolerant species. Their reaction capacity makes them good bioindicators, given that they are differentially sensitive to pollutants, responding gradually to a wide spectrum of stress levels. Moreover, they are abundant and relatively easy to collect and identify, and have a long enough life span to exhibit environmental quality [Silveira, 2004]. Some kinds of benthic macroinvertebrates are shown in Figure 2.

Silveira [2004] underscored the influence of alluvial vegetation on the life of benthic macroinvertebrates. He observed that it interfered in the ecology of aquatic environments, providing shelter, protection, nutrients and organic matter.

Figure 2. Some kinds of benthic macroinvertebrates. a) Tanypodinae; b) Chironominae; c) M. Tuberculata.

3. MATERIALS AND METHODS

Campaigns were conducted to measure water discharge and collect bottom sediment samples in two cross sections located in the lowland section of the Pitimbu River over 330 days, for a total of 11 monthly campaigns. The monitoring period (13/11/07 to 03/10/08) was marked by the occurrence of maximum events, spanned both the dry season of 2007 and the rainy season of 2008. The measurement and sample collection campaigns were followed by sediment analyses, conducted at the entomology laboratory of UFRN.

The measurement of water discharge was carried out using a hydrometric micropropeller at equally spaced vertical elevations in the transverse cross section. Fluvial sediment samples were collected by using a *Van Veen* dredge (10 kg weight, 2.0 ℓ sample). The methodology used for sediment sample collection considered the wet perimeter of the transverse cross section [Carvalho *et al*., 2000]. After quartering, the samples were washed in a 250μm sieve and stored in 80% (v/v) alcohol/ethanol solution. In biological analysis, the samples were sorted and the organisms were manually captured with the help of a loupe. The organisms were separated into tubes, identified and counted. Organism identification was based on morphological characteristics and multiple taxonomic keys [Edmunds *et al.,* 1963; Mccafferty & Provonsha, 1994; Niesser & Melo, 1997]. Organism identification and counting enabled characterization of the environmental quality of organisms as a function of the sensitivity level of the existing biodiversity. To determine the degree of organism sensitivity we used the tolerance values of studies conducted by Alba-Tercedor [1996], Cota *et al.* [2002] and Figueroa *et al.* [2003].

4. RESULTS AND DISCUSSION

4.1 Hydrologic Regime

The records of daily rainfall observed in the study period are shown on the graph in Figure 2. The rainy season began on 12/03/2008 and ended on 30/08. Total rainfall for the period was 2495 mm, a value above the historical mean. The events observed on 08/06 (271 mm) and 01/07 (260 mm) were considered exceptional. A decrease in flows was observed in the dry season, despite the occurrence of randomly spaced events with the water level at less than 20 mm. The rainy season accounted for the increase in flow rate to a maximum of 10.6 m^3/s, corresponding to 17 times the flow rate at the end of the recession period (Figure 3). This behavior reflects the effect produced by sudden filling, with a significant surface contribution from the impermeable areas of the basin. Depletion behavior of the hydrograph at the end of the rainy season shows the water retention capacity of the soil.

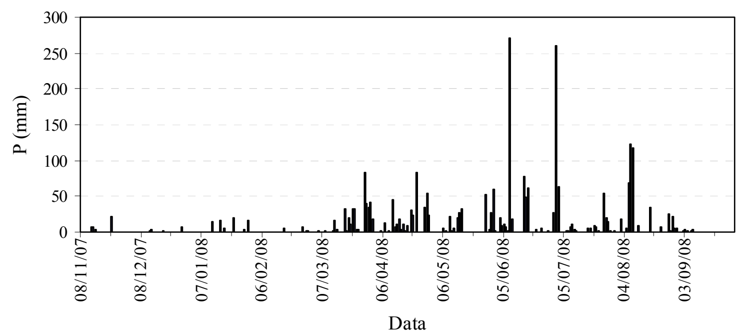

Figure 2. Daily precipitation at LARHISA station during the study period.

The hydrograph recession phase reflects the behavior of water storage and aquifer transmissivity in the basin. Although recession is a highly variable process in both time and space, it is possible to adjust a regional expression of groundwater flow. Recession reflects the critical state of the water supply. The recession process is influenced by geological factors in addition to land occupancy and use in the basin.

According to Hall [1968], the recession curve allows the adjustment to a linear exponential function using the Depuit-Boussinesq equation,

$$Q_t = Q_0 . e^{-\alpha . t} \qquad (1)$$

where Q_t is the flow at time t, Q_0 is the flow at the onset of the recession phase, $e^{-\alpha}$ (equal to k) is a recession constant used as an indicator of the influence of base runoff in the basin. Residence time (three days) corresponds to the mean duration of base runoff. The methodology used in the analysis of the recession hydrograph consisted of a linear adjustment of flows on a logarithmic scale. The values of parameters Q_0 and α are presented in Table 1.

The values obtained suggest high recession rates, with a strong effect of base runoff. The residence times obtained in the two sections were 7.7 and 8.0 days, respectively.

Table 1. Pitimbu river recession parameters at the monitoring sections.

Section	*Qo* (m3/s)	*α*	*k*	*Tres* (days)	R²
1	0.623	0.13	0.879	7.72	0.87
2	1.24	0.125	0.883	8.01	0.91

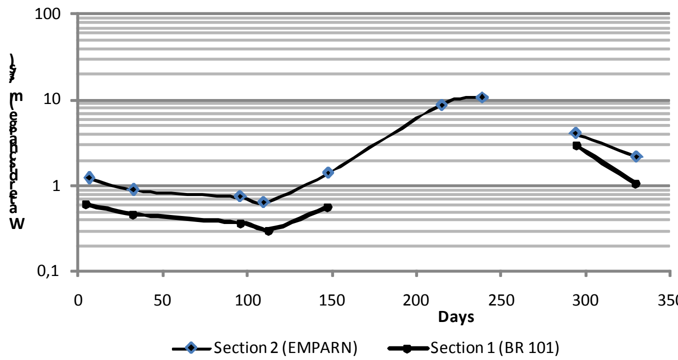

Figure 3. Flow behavior during the study period.

Water discharge data revealed an increase between the sections of 1.982. The increased flow reflects the effect of base runoff (river-aquifer) in the stretch of river studied.

Biomonitoring analyzed the presence of benthic macroinvertebrates in the fluvial bed sediment from the transverse cross sections of the Pitimbu River. Sediment samples varied between 0.4-0.45 kg. Organism identification in the laboratory showed a diversity of benthic macroinvertebrates composed of nine taxa.

In section 1, located upstream from the bridge over highway BR-101, a predominance of resistant groups *Ortocladinae* and *Chironominae* was observed, suggesting a high level of ecosystem degradation. The absence of sensitive organisms, along with low biodiversity, confirms compromised quality. Table 2 shows the groups of benthic organisms observed in section 1, grouped by taxonomic family and by degree of sensitivity to organic pollution.

Table 2. Benthic organisms at section 1at the 2007-2008 dry season.

ORGANISMS	TOTAL	Sensitive	Tolerant	Resistant
M. Tuberculata	1			×
Orthocladiinae	24			×
Chironominae	31			×
Policentropodidae	7		×	
Tanypodinae	7		×	
TOTAL		0	14	56

In section 2, groups of organisms were observed from the three levels of sensitivity to organic pollution. The dominant group, *M. Tuberculata,* reflects the damage to ecosystem quality. Table 3 shows the benthic organisms observed in this section, by taxonomic family and sensitivity level.

Table 3. Benthic organisms at section 2 at the 2007-2008 dry season.

ORGANISMS	TOTAL	Sensitive	Tolerant	Resistant
M. Tuberculata	45			×
Orthocladiinae	11			×
Chironominae	11			×
Policentropodidae	1		×	
Tanypodinae	2		×	
Corduliidae	2	×		
Hydropsychidae	10		×	
Helicopsychidae	2	×		
Hidroptilidae	1			
TOTAL		4	13	56

The organic sensitivity of each benthic invertebrate group shows that greater damage occurred to ecosystem quality in section 1. In this section, the absence of the sensitive organisms *Corduliidae* and *Helicopsychidae*, observed in section 2, signal the degraded quality of the aquatic ecosystem.

5. CONCLUSIONS

The results obtained in the present study allow us to conclude the following:

- Observed water discharge during the dry season enabled the adjustment of Depuit-Boussinesq parameters. These parameters show relatively high recession rates, residence time of 8 days and strong non-confined river-aquifer interaction. Nevertheless, the BHRP undergoes uncontrolled urban settlement, which tends to impact water quality in the medium-term;
- Biomonitoring results reveal signs of aquatic ecosystem degradation by heavy metals contamination (Copper and Cobalt), evidenced by the lack of sensitive benthic organisms and abundance of resistant organisms;
- The current condition of the aquatic ecosystem underscores the importance of policies to control and protect the basin; otherwise the level of degradation may soon reach levels that will make the water unfit for human consumption.

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