Water quality monitoring system approach to support Guapi-Macacu river basin management, Rio de Janeiro, Brazil

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ABSTRACT

Water quality monitoring is an essential component of the integrated water resource management. The Brazilian National Water Resource Policy establishes the framework for maximum use with proper management of the resource with public participation at the river basin. The Guapi-Macacu River Basin (GMRB) located in north-eastern region of Guanabara Bay Basin in Rio de Janeiro (Brazil) consists of protected areas, with good water quality and quantity in the upper reaches of the basin and head waters. The general objective was to analyse the current water quality monitoring system to contribute for the GMRB management plan. The State Institute of Environment (INEA), is responsible for the water quality monitoring within its environmental monitoring system in river basins. Variation of parameters, frequencies and sampling sites occurs between INEA and another entity. Based on the results of this research, recommendations were given for the newly established management plan.

Key words: *water quality monitoring, Integrated Water Resource Management, environmental monitoring system.*

Introduction

Recently, the "Water Crisis" has caused many initiatives of Water Quality Management to reduce and prevent the negative impacts of anthropogenic activities and climatic changes on the water sources for human consumption and maintain the *status quo* of water bodies (UNEP, 2003; UN Water, 2006; IPCC, 2007). Therefore, water quality monitoring system has taken the 'spotlight' of Integrated Water Resource Management at the River Basins level; with the integration of research and advanced technology (Ward, *et al.*, 2003; Ribbe, 2008) to contemplate and link the components of information needs and data collection (Figure 1).

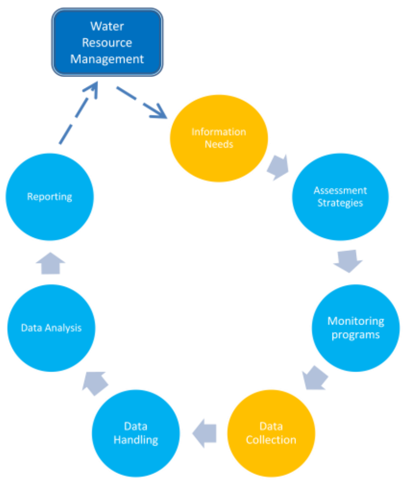

Figure 1: Water Quality Monitoring: a major component of Integrated Water Resources Management.

Since the ancient civilizations, three main focuses of water governance policies have remained constant through time: 1) controlling water contamination, 2) water policies must abide with other social and economic policies and 3) establishing institutional mechanisms (Nanni, 2007; Iza, 2009). Nowadays, most transitional and developing countries have Decentralized-Communitarian Water Policies, containing the three main focus mentioned before (Global Water Partnership, 2007). The importance of water quality monitoring is well stated in the Brazilian National Water Resource Policy (Política Nacional de Recursos Hídricos, PNRH) in its objectives "to secure for the present and future generations the necessary water supply, in parameters of quality adequate for the respective uses" (Art.2º, Cap. II, Tit. I, Lei 9.433) (Agência Nacional de Águas, 2005). Inspired by the French Water Resource Management, having the river basins as management units, the implementation phase has been relative in each state, with river basin characterization and institutional reforms (Porto, 2008). It has been encouraged the improvement of knowledge of water availability (water quality and quantity) and demand (multiple uses) in each hydrographic region. Moreover, emphasizing a clear definition of the protection and use of groundwater in the legislation system (Porto, 2008). To ensure effectiveness, an evaluation adopted for a water quality monitoring system should cover all relevant technical design features, including selection of sampling sites, sampling frequencies, variables to be monitored, synergy, and sampling duration (UNEP, 2003).

In Rio de Janeiro (RJ) efforts are being made to implement water quality monitoring systems and measures as stated by national and state laws through the recent (2009) State Institute of Environment (INEA), a decentralized watershed-based organization (http://www.inea.rj.gov.br). RJ State, apart from other few activities, diverse agricultural activities and practices, in the north eastern rural region has contributed to the slight degradation of water quality in the region. Recently, the construction of the Petrochemical Complex (COMPERJ) in the municipality of Itaboraí, south of the Guapi-Macacu River Basin (GMRB) is the largest petrochemical industrial undertaken in the history of Brazil with a total investment of around US$ 8.5 billion (Torrico, 2008). The Complex will need a large amount of water supply and manpower, this will possibly cause impacts to land use dynamics to the GMRB. Therefore, it needs a good water quality monitoring system to provide adequate information to the decision making to maintain good water quantity and quality standards. Hence, the General Objective of this thesis was to analyse the current water quality monitoring system to contribute for the Guapi-Macacu river basin management plan. To accomplish this general objective the following specific objective were made:

- To understand the current implementation of the water monitoring framework in the river basin.
- To identify the major causes and impacts that at the short and long term has defined the water monitoring activities in the state.
- To identify the effectiveness of the water monitoring activities.

The Brazilian Atlantic Forest (Mata Atlântica) classified as a biodiversity Hotspot, located between the coordinates 3°S to 31°S and 35°W to 60°W, along the Brazilian coast, had a vegetation cover of 148,194,638 ha. The remaining vegetation cover ranges from 11% to 16%, existing in small fragments (less than 100 ha each) that are isolated from each other. Amongst the largest fragments, the Serra do Mar is the largest fragment (Costa, 2006; Ribeiro *et al.*, 2009).

Guapi-Macacu River Basin found within the Serra do Mar, is located on the eastern region of the Guanabara Bay Basin (Region V) (figure 2). It consists of Guapi-açu and Macacu rivers, with a catchment area of about 1,640 km^2 and an estimated population of 106,341 habitants (Dantas, 2008). It contributes to the water supply of nearly 2.5 million inhabitants in the municipalities of Cachoeiras de Macacu, Guapimirim, Itaborí, São Gonçalo and Niterói. (Pedreira G., *et al.*, 2009).

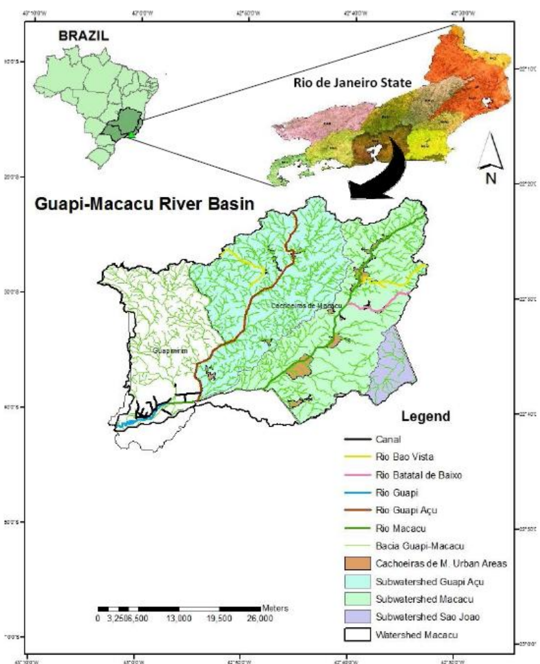

Figure 2: Study Area.

Methodology

The methodology involves a five-step procedure, which will provide the tools to obtain the three specific objectives along with the rapid analysis of the current water quality monitoring system carried out at the river basin within the existing water resource management framework. It is a combination of two conceptual approaches, Driving Force-Pressure-State-Impact-Response (DPSIR) and Strategic Environmental Analysis (SEAN), (Organization for Economic Cooperation and Development, 1994; European Environmental Agency, 1999; Kessler, 2003; Neves, 2007). See figure 3.

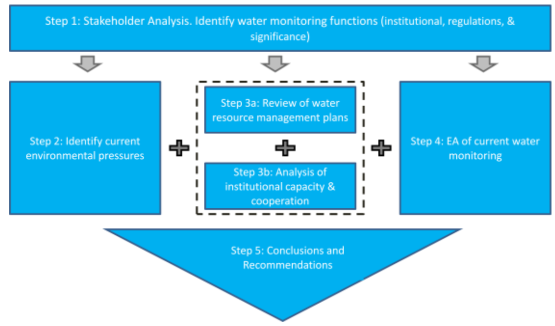

Figure 3: Conceptual methodology for thesis research.

In this work, secondary source information was collected from six (6) sources.

In step one (1), a stakeholder analysis on the current water resource management of the Guapi-Macacu River basin was done, including the water quality monitoring system in the river basin.

Secondary source information was a priority for step one (1) and to step three (3); to accomplish the first and second specific objectives. These data were organized in a data base to contribute to the others steps (2 and 3b, figure 3).

For step 4, an Effective Analysis (EA) with the first mentioned approach of the current water monitoring in a specified area of the river basin was carried out. The water quality data, including list of parameters, waypoints and the frequency of monitoring, were collected. ARCGIS (version 9.3) from ESRI was used to presents maps from GMRB:

- To show current water monitoring sites and drainage net in Guapi-Macacu river basin;
- To propose effectiveness water monitoring network for Guapi-Macacu river basin.

Finally the main findings to improve water quality monitoring in Guapi-Macacu river basin were presented. They are available to the organizations responsible in water quality monitoring in the River Basin. Simultaneously, it will be found in the database of the DINARIO Project to contribute to the general objective of the project.

The fieldwork for this research was done in three stages in a period of three months (March – May 2010) by means of three stages following the work plan in figure 4. First, the collection of secondary source information was prioritized for the activities for the first and second specific objective (step 2 and 3a, figure 3). Documents, both in soft and hard versions were collected.

The second stage consisted, of secondary source information collection, observation of the Micro–Basins within the Macacu River (Guapi-Macacu Sub-Basin): Batatal, Regua Area and São José da Bão Morte. Digital pictures were taken from each site. Waypoints were taken at sites that showed indications of environmental pressure due to the activities around or at the site (step 2, figure 3).
Finally, the third stage consisted of identifying and interviewing key-informants using semi-structured interviews to (determin, evaluate and measure) institutional capacity and cooperation (step 3b, figure 3).

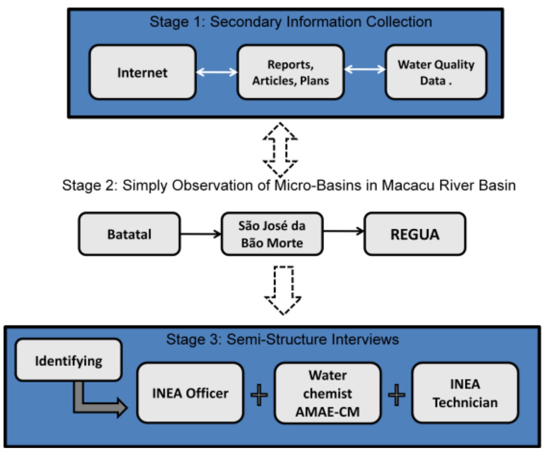

Figure 4: Fieldwork Activities.

Finding and Discussion

Water quality monitoring in a country as big as Brazil is hindered by the heterogeneity of existing monitoring networks, mostly operated by federal states that have adopted different approaches (number of parameters, sampling frequency and others) in the implementation of their monitoring system. The annual report of the Panorama of the Quality of Superficial Water (2004) stated that seventeen out of the twenty-seven Federal States operate and maintain water quality monitoring networks, with a total of 2,259 sites, with a variation of parameters and frequency.
In 2002 and 2006, the Brazilian National Water Agency (Agência Nacional de Águas, ANA) conducted two National Water Quality Monitoring (NWQM) campaigns to determine the water quality status of surface freshwater. They used three indexes; one of them was the Water Quality Index (WQI). In those campaigns water data were identified with some kind of risk of water contamination through the discharge of untreated sewage in water bodies. The WQI composed of nine (9) Parameters, including the three parameters in the 2009 basic hydro meteorological network. Dissolved oxygen (DO), fecal coliform, pH, biochemical oxygen demand (BOD), temperature, total nitrogen, total phosphorus, turbidity and total residue.
In June 2010, the National Program of Water Quality Assessment (Programa Nacional de Avaliação da Qualidade das Águas, PNQA) was launched by ANA to once again to assess the water quality of the country. PNQA is an initiative started in 2006 to achieve a standardize system of water quality monitoring in the hydrographical regions and federal states for 2015. The criteria were as followed; Percentage of hydrographical basin monitored, types of parameters analyzed, frequency of sampling and form of information availability within the states (Mazzola, 2009).
It was observed that the water quality monitoring in GMRB is part of the environmental monitoring program in RJ state carried out by INEA. They do the water quality monitoring: 1. To monitor the industries in a compliance with the regulation of environmental licensing. 2. To report to the CECA. The Branch of Information and Environmental Monitoring has five sub-branches including all the components of a water quality monitoring system, except information needs and assessment strategies; even though the water monitoring system is done as part of the environmental monitoring. Under this branch, INEA technicians do water quality monitoring, including the collection of water samples, the water analysis in laboratories, and the reports of results, the water quality assessment and the reports for the other branches of INEA and the Department of Environment. INEA does systematic traditional and automatic water quality monitoring. The first monitors the trend of water quality conditions over time, providing data from a list of parameters and pre-established frequency. The latter gathers data from limited number of parameters at many short intervals as frequency.
Figure 5 shows, apart from INEA, the institutions that do water quality monitoring in the GMRB. ANA has one monitoring site out of the 54 water quality data monitoring sites located in GMRB in the urban area of Papucaia in the municipality of Cachoeiras de Macacu.
It was observed that there were two governmental agencies and a public-private Water Company that conduct water quality monitoring in the Guapi-Macacu River Basin (figure 5).

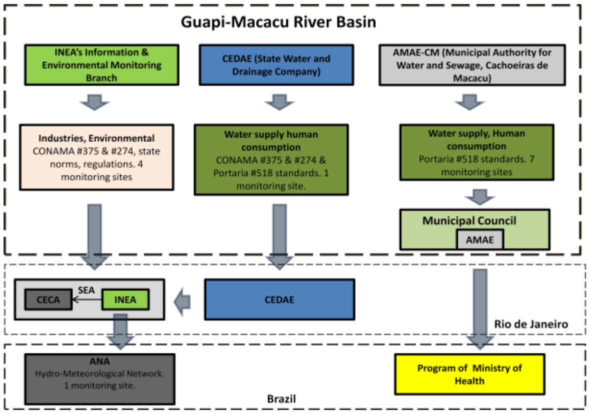

Figure 5: Water Quality Monitoring at GMRB.

- AMAE of Cachoeiras de Macacu was the Municipal Authority of Water and Sewage. They do the water quality monitoring to maintain the water quality of water supply sources for human consumption.
- CEDAE is the State Company of Water and Sewage. They do the water quality monitoring: 1) to maintain the water quality of water supply sources for human consumption, and, 2) to treat wastewater.

CEDAE has only one water supply capture area in the river basin; hence it is responsible to monitor the water being collected from the Imunana Canal. Figure 5 shows the current water quality monitoring systems in GMRB. However, the results show two observation of a complete water quality monitoring system:

- They participate in the complete monitoring system by doing the monitoring program, data collection, and data handling.
- There are three water monitoring systems conducted by three different institutes. CEDAE and AMAE-CM have the same reasons to participate in the monitoring system. While INEA has different reasons because the water quality monitoring is part of environmental monitoring in the river basins of Rio de Janeiro.

This section consist of an Effectiveness Analysis based on the identified environmental pressures, the relevance of the selection of monitoring site, sampling frequency and parameters; and the water quality data sharing to identify improvements in the current water quality monitoring system for the management plan of GMRB.

Based on the secondary information collected, the main indirect environmental pressures of water quality are related to land use changes in the river basin.

Evidently, the land use changes, establishments of industries and untreated domestic sewage have rapidly occurred in the studied river basin, having an impact on the quality of water, specifically:

- Intensive farming contributing to the diffuse sources of water pollution. Thus, the river basin will receive urban effluents with extremely toxic agrochemicals. This agricultural activity has occurred in areas, like São José da Boa Morte, a low population density community, where neither INEA nor AMAE have sampling sites. Even though, AMAE has identified a monitoring site in Bonanza but there are no reports of samples taken at this site. Another farming area is Batatal, where farming occurs alongside the river bank.
- Potential Industrial effluent. The increase numbers of industries establishment are widely distributed in the sub-basins. Apart from the construction of COMPERJ, there is also water purifying industries.
- Domestic sewage. This type of water pollution is considered very serious in the city of Cachoeiras de Macacu because AMAE presently only conducts water quality monitoring at water sources for human consumption. Moreover, the water of the Macacu River that passes through Chacoeira de Macacu city also passes through other two communities downstream and finally reaches the Imunana Canal, capture area by CEDAE for human consumption to metropolitan cities.

In 2004, according to the Tribunal de Contas do Estado do Rio de Janeiro (TCE-RJ), the fastest growing activity was farming with 14.54% (BioAtlântica, 2009). Irrigation is a major activity that requires water quantity for agriculture lands. As found in the literature review, nearly 50% dramatic increase of this activity in a very short period of time. In 1996, the agriculture census recorded a total of 1,231 Ha irrigated; in 1999, Costa obtained data for the municipalities of Cachoeiras de Macacu, Gaupimirim and Itaboraí for a total of 2,013 ha irrigated. Three sites were visited, two in the Guapiaçu river sub-basin and one in the Macacu river sub-basin. Figure 6 below shows the location and names of the visited sites.

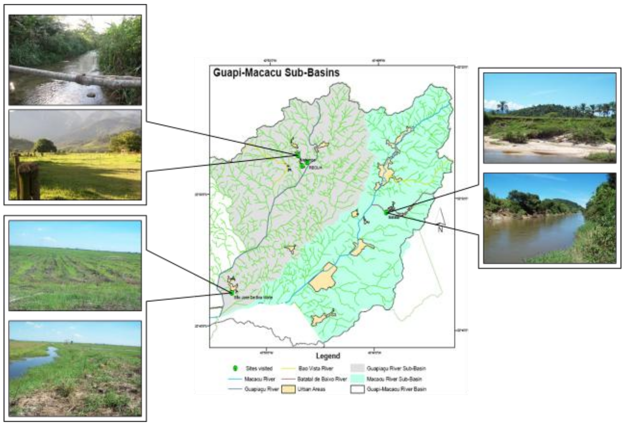

Figure 6: Agriculture areas visited.

Also, it is noted that the tributary in the Batatal site and the Guapiaçu river beside the forest reserve (REGUA) passes through an urban settlement, meaning that water is obtained directly from these water bodies for irrigation and livestock. While at the site of São José da Boa Morte, apart from water source for the intensive agriculture; the runoffs are delivered in the streams connecting to the Guapiaçu river. Moreover, there is an urgent need of attention at this site to control or prevent flooding.

Geographically, INEA and AMAE-CM are the only institutions conducting water quality monitoring in the Guapi-Macacu river basin, since CEDAE has its monitoring site in its pumping station which is not located in the sub-basins of Guapiaça and Macacu rivers. Therefore, with just two monitoring sites by INEA and closely located monitoring sites by AMAE-CM it is evident that both sets of monitoring sites are non-representative because their spatial location does not supply representative information to monitor the present and potential water quality impacts caused by the identified environmental pressures.

However, AMAE-CM, being the local authority has monitoring sites in the two river sub-basins, seven in Macacu river sub-basin and two in Guapiaçu river sub-basin. According to the Interviewee, the two water sources have good water quality and abundant water. The two sites that are located in Guapiaça river sub-basin are both wells, and are in two urban areas, Bonanza and Maraporâ.

The types of parameters measured by INEA, AMAE and CEDAE were from the type (a) physical-chemical, (b) microbiological, (c) organic and (d) inorganic. Six (6) parameters were measured by the three mentioned institutions. While seven (7) parameters along with the organic and inorganic parameters are measured by INEA and CEDAE.

The frequency of sampling varies between the provisions of resolution CONAMA # 357/2005 and Ordinance # 518/2004. For the ordinance # 518/2004, the frequency of sampling in a monitoring site for physical-chemical parameters are taken four-times a day, the microbiological parameters are taken twice a month. AMAE and CEDAE use the parameters in ordinance # 518/2004 and INEA uses the parameters of resolution CONAMA # 357/2005.

There is a lack of water quality data management with no identifiable share mechanism between the two water monitoring governmental institutions; AMAE-CM and INEA. As stated, the Environmental Monitoring Branch of INEA monitors all the rivers in Rio de Janeiro State to comply with its responsibilities. While AMAE-CM monitors the water sources in the municipality of Cachoeiras de Macacu. AMAE-CM should provide water quality data to INEA, to have a better panorama of the water quality of the river basin with all monitoring sites.

Conclusion

The National Policy of Water Resources implements the national and state water resource management system, the River Basin Management Plan and the water body classification based on their multiple uses for water use charges. At the national level, ANA is responsible in maintaining a national monitoring network in every hydrographical region, while at the river basin level, assist in collecting and distributing the information. ANA has established systems of information (data bases, center of discussions, and information linkage about water quality/quantity).

This study mainly focused on the water quality monitoring system components of monitoring program, data collection and data handling in GMRB. In Rio de Janeiro, as described with the case study of the Guapi-Macacu river basin, the State Institute of the Environment conducts water quality monitoring within their environmental monitoring system. However, the sharing of water quality data is not as effective as at the national level, although each agency has well established objectives, water quality conditions and standards, collection schemes and data analysis.

Overall, the water quality of the rivers and tributaries in the Guapi-Macacu River Basin can be kept within the accepted standards, while the participation of the sub-committee at the East section of the Guanabara Bay be active, and therefore be a prime example on the timely and spatial use of the water resource in the river basin.

The following are recommendations to improve water quality monitoring for the Guapi-Macacu River Basin Management Plan.

- Carry out a Cost-Benefit Analysis of the two current water quality monitoring systems in GMRB.
- Elaborate a Survey of potential monitoring sites in GMRB, considering the identified environmental pressures to the water quality.
- Establish an information exchange mechanism between AMAE and INEA.

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