



Evolution of the Monitoring Water Quality System in Ipojuca River Basin, Brazil

M. Sobral,¹ S. Montenegro,¹ G. Gunkel,² A. M. L. Barros,¹ J. Aureliano³

¹ Federal University of Pernambuco (UFPE), Civil Engineering Department, Rua Acadêmico Helio Ramos s/n, Cidade Universitária, Recife, PE, Brazil CEP 51.470-010, msobral@ufpe.br, suzanam@ufpe.br, maciel_alessandra@hotmail.com

² Technical University of Berlin (TU Berlin), Department of Water Control, Berlin, Germany, guenter.gunkel@tu-berlin.de

³ State Environmental Agency of Pernambuco (CRRH), Brazil, jaureliano@cprh.pe.gov.br

Abstract

The monitoring of water quality is one of the environmental management instruments established by the Brazilian Environmental Policy. The objective of the presented article is to show the evolution during the last 20 years of the water quality monitoring system for the Ipojuca river basin, located in Pernambuco's State. The Ipojuca river is situated in the semiarid and coastal zones of Pernambuco state. The dominant impacts on water quality of the river are domestic sewage input in the upper catchment and sugar cane cultivation and processing in the lower catchment. Long-term monitoring data was used to demonstrate the impact of sewage discharge on the river's self-purification capacity due the use of stillage (wastewater from cane processing) for fertilization and irrigation (fertigation). Contamination is done by a bio-alcohol factory with annexed sugar cane cultivation. The river's main ecological problems are water heating, acidification, increased turbidity, oxygen imbalance, and increased coliform bacteria levels. The monitoring system should be improved aiming its effective use as a decision support tool and popular participation in the environmental control practices and water resources management. It is concluded that to overcome the deficiencies, it is necessary to consolidate the participation of society into organizations which take part in the environmental control, as well as the implementation of water agencies and the water price, which will give the basic structure to improve the environmental conditions of the river basin.

Keywords

Brazil; Ipojuca; monitoring; Pernambuco; water quality; water contamination

I. Introduction

The monitoring of water quality is one of the environmental management instruments for river basin management and was too established by the Brazilian Environmental Policy. In Brazil, the classification of the water bodies according to uses was done by resolution N° 357/2005 of the National Environmental Council-CONAMA (MMA, 2005), and in several Brazilian states it has served as new standard in monitoring and controlling water pollution as well as target in river basin management. According to it, waters were classified as fresh (special, classes 1, 2, 3 and 4), brackish (special, classes 1, 2 and 3), and saline waters (special, classes 1, 2 and 3). For each class, conditions and standards limits of several water quality variables were also defined (MMA, 2005).

One of the fundamental guideline for implementing this instrument is that it is not be based on the current state of the water body, but it gives a goal for quality levels needed for the provided use of the water, in particular drinking water. This concept of water classes related to water use should promote the monitoring forces on every level of governmental water management. This is the basis for any planning processes within a watershed. Barth (1999) pointed out that water quality classification of rivers must be seen as a goal to be reached over time, while in many other countries a discussion is going on to optimize monitoring programs to avoid data agglomeration and the determination of non valuable data. A new concept applied in many countries such as the United States of America and the European Community is a direct correlation between ecosystem quality, which means ecosystem health and water uses (EC, 2000). The Brazilian water quality evaluation also must be seen with regard to these extensive water quality concepts (Sobral et al. 2008).

The Ipojuca, one of the largest coastal rivers in the state of Pernambuco, Brazil, shows high levels of water pollution (Sobral et al. 2002; MMA 2003; Gunkel et al. 2007) and is used for fishing, abstraction of drinking water and irrigation water (PNMA, 2003), but is not yet classified according to CONAMA Resolution 357/2005. Previous work concerned the development of a management plan by the Secretariat of Science, Technology and Environmental Science (SECTMA, 2001) and the Secretariat of Water Systems (SRH, 2002). Deficiency exists on the application of environmental norms mainly between the environmental policy and the transformation to a local level, but also between environmental policy and the water quality management.

The objective of the presented article is to show the evolution during the last 20 years of the water quality monitoring system for the Ipojuca River basin. The series of data collected by the State Environmental Agency (CPRH) is analyzed in order to point out the strengths and weakness of the monitoring system and to define a model for restructuring the existing water quality monitoring system in Pernambuco's State.

II. Materials and methods

A. Study area

The Ipojuca watershed, located in Northeastern Brazil, in Pernambuco State covers an area of 3,433 km², with a total river length of 290 km (08° 09' 50'' - 08° 40' 20'' S and 34° 37' 52'' - 37° 02' 48'' W) and flows in west-eastern direction into the Atlantic Ocean (Fig. 1). The water flow regime is characterized by the annual change from dry to rainy season as well as periodically occurring long-time dry cycles. Annual rainfall varies from 700 mm (with rain period from February to June) in the upper basin to 1500 mm in the littoral region (with rain period from March to August), the evapotranspiration

amounts about 2,400 mm. The flow regime in the first third of its total length is intermittent. In the lower course, flow rates vary from 2 m³/s (dry season) to 35 m³/s (rainy season). The annual mean temperature is approximately 27 °C (SECTMA, 2001).

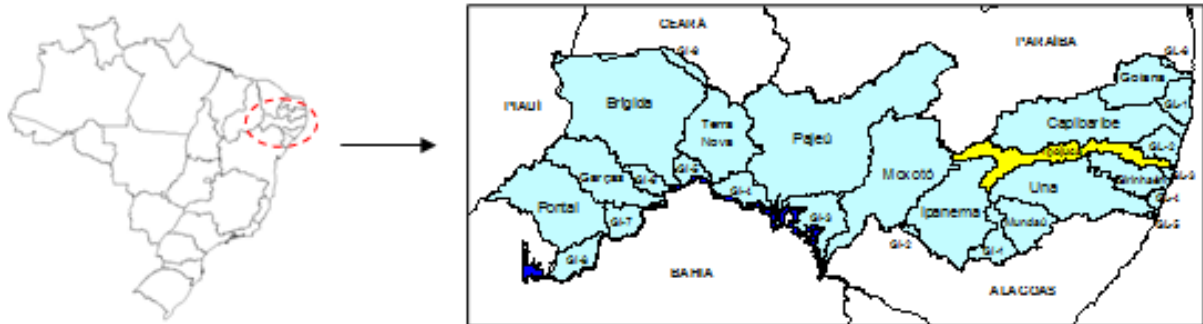


Fig. 1. Brazil, State of Pernambuco and Ipojuca River Basin.

The area's population density is 161 inhabitants/km², mainly concentrated in urban centers (80 %). Land use in the upper catchments is dominated by food industry and small villages without any sewage treatment facilities. The lower section of the river's catchments area is predominantly influenced by sugar cane monoculture and processing for bio-alcohol production, while the upper water course with the estuary zone is mainly affected by domestic sewage as well as by wastewater discharge from agricultural and industrial production. The river's main ecological problems are salinization (due to geological background) in the upper course, water heating, acidification, increased turbidity, oxygen imbalance, and increased coliform bacteria levels due to sewage and waste water discharge. Precipitation-related wash-off and wash-out causes significant contamination, mainly in the sugar cane cultivation area (Gunkel et al., 2007).

B. Sampling and analytical methods

Monitoring as well as water analyses have been carried out by the CPRH, using the US APHA Methods (1995). Sampling frequency was planned to be once a month, but as the upper river section is not perennial, sometimes sampling is not performed because there is no water flow in the river.

III. Results and discussion

A. Evolution of the monitoring water quality system

A programme for monitoring water quality should be planned on the basis of local objectives and characteristics. Sample collection, laboratory analysis and data analysis depend upon these elements. The common aims of a water quality monitoring programme are: specific studies, calibration of mathematical models, periodic evaluation of water quality, evaluation of patterns according to legislation, operational control and emergency studies (Sobral et al. 2002; Von Sperling, 2007). The Pernambuco State Environmental Agency (CPRH) has more effectively invested in actions for controlling sources of pollution, and thus has implemented water quality monitoring programs with

this objective. As a result, systematic records of the surface water resources have been produced, but with a high cost and inefficient from the point of view of controlling contamination, sometimes picturing the water quality situation in the watershed far from the reality.

In the last ten years, 29 water quality monitoring stations were located within Ipojuca River Basin. Out of them, seven stations have never really been monitored, two have been relocated, six have been deactivated and fourteen are fully operating. In 2004, the monitoring system was restructured based on the land use, location of the sources of pollution and on the purpose of the water use within the watershed. Six water quality homogeneous zones were identified: environmental interest, agro industry, livestock, dairy farms, urban/industry and multiple cropping. The restructuration of the water quality monitoring system has created nine new stations, disabled two stations and relocated one station. The new stations are related to springs, reservoirs, upstream reservoirs, estuary and sea (SECTMA, 2005).

It has been established through the restructuration to keep the previous stations, so that historic data series would not be interrupted. The frequency of sampling depends upon the location of the station. For the intermittent section of the river, the frequency is annual, with sampling in April. For the stations upstream reservoirs, perennial spring in uplands, in the river estuary and the sea zone influenced by the Ipojuca river, the sampling frequency is each semester with analyses being performed on April and October. For the perennial sections of the river, the sampling frequency is each two months with analyses being performed on April, June, August, October and December.

B. Monitoring parameters

Throughout twelve years (1995-2006), several parameters have been included and other excluded from the water quality monitoring program. Only three parameters (dissolved oxygen, BDO₅ and fecal coliform bacteria) have been continuously analysed during this twelve years period. For instance, in 1995, there are records of dissolved oxygen, DBO₅, ammonium and fecal coliform bacteria. In 1997, there are records of pH, electrical conductivity, turbidity and fecal coliform bacteria. In 1999, there are records of temperature, electrical conductivity, total concentration of phosphorus, chloride, potassium and heavy metals (Cd, Pb, Cu, Cr, Fe, Mg, Ni, Zn). In 2004, with the restructuration of the monitoring system, turbidity, ammonium, nitrate, nitrite and total solids have been established as the parameters to be analysed. The established biological parameters are phytoplankton, zooplankton and chlorophyll a.

C. Evaluation of the water quality

The water quality in Ipojuca river watershed has been evaluated on the basis of the established patterns according to CONAMA n° 357/05. The following points have been observed:

- the observed high levels of fecal coliform bacteria are evidence of strong contamination by domestic sewage;
- the intermittent section of the river exhibits high concentration of chloride, associated to the soils type in the area. In the perennial sections of the river, one of stations presents high concentration of this parameter, and this may be associated to seawater influence;
- the observed concentrations of dissolved oxygen equal to zero and high DBO₅ values observed downstream urban areas (intermittent section); sugar cane industries (perennial section) are evidence of domestic sewage and industrial residues disposal exceeding the self- purification capacity of the river;

- in all the stations, high concentration of phosphorus have been observed, above the threshold established by the legislation, especially in the intermittent section of the river, and this may be related to domestic sewage;
- high values of ammoniac nitrogen have been observed on the stations located in the intermittent section of the river, giving evidence of the pollution caused by domestic sewage;
- high concentration of potassium were observed in the beginning of the regular period of processing sugar cane by the industry, giving evidence of the contamination due to the residues from fertigation (use of stillage, the wastewater from cane processing, for fertilization and irrigation), which may have been disposed directly into the river or reaching the river through the groundwater flow.

Due to the enhancement in nutrients, the Ipojuca river is eutrophized in some sections, exhibiting high quantity of aquatic macrophytes.

IV. Conclusions

A significant number of parameters are considered in the water quality monitoring program. In the following the main improvements from the restructuration of the system since 2004 are pointed:

- periodic evaluation of the water quality according to the legislation;
- consideration of the hydrologic regime in the watershed (intermittent and perennial sections of the river);
- consideration of biological parameters (phytoplankton, zooplankton and chlorophyll) in the monitoring programme;
- inclusion of nine monitoring stations, for monitoring spring, reservoirs, river estuary and sea water under the influence of the river;
- inclusion of at least one monitoring station in each zone with homogeneous land use; prior to the restructuration the monitoring was performed downstream the sources of pollution;
- use of water quality indicators.

The location of the current monitoring stations allows the water quality characterization by homogeneous zones, but it does not allow the identification of the source of pollution. This is due to the fact that there aren't monitoring stations upstream the main sources of pollution, such as urban areas and industries. Even though the occurrence of remarkable improvement in the pollution control process throughout the recent years, a long term analysis is not possible due to discontinuity of observation for some of the monitoring parameters and absence of simultaneous observation periods for all the parameters. Aiming the improvement of the monitoring system, the following recommendations are withdrawn:

- to locate new monitoring stations upstream urban areas and industries;
- to analyse nitrite, nitrate and ammonium and phosphorus with higher frequency in order to better evaluate the dynamic of nutrients, especially in the intermittent section of the river;
- to perform measurements of the river discharge on the water quality sampling stations;
- to enhance surveillance on the sugar cane industries, especially on the time of processing the sugar cane, in order to avoid direct discharge of the effluent into the river;
- to include evaluation of potassium in the intercropping periods, for its assessment throughout the year.

The inclusion of potassium in the monitoring program is considered a step forward, since the ion is an indicator of vinasse incoming and it can be used in the evaluation and control of tools aiming to diminish the water resources contamination by the fertigation process.

The monitoring system should be improved aiming its effective use as a decision support tool and popular participation in the environmental control practices and water resources management. It concludes that to overcome the deficiencies, it is necessary to consolidate the participation of society into organizations which take part in the environmental control, as well as the implementation of water agencies and the water price, which will give the basic structure to improve the environmental conditions of the river basin.

References

- APHA (1995) Standard Methods for the examination of water and wastewater. American Public Health Association (ed.), 19th edition. Washington D.C.
- Barth, F. T. (1999) Aspectos institucionais do gerenciamento de recursos hídricos. In: Rebouças, A. Braga, C. B. and Tundisi, J. G. (eds.). *Águas doces do Brasil*. São Paulo. Escrituras Editora. pp. 565-599.
- EC (2000) Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy. *Official Journal of the European Communities (OJ L 327)* on 22 December 2000.
- Gunkel, G., Kosmol, J., Sobral, M., Rohn, H., Montenegro, S. & Aureliano, J (2007). Sugar Cane Industry as a Source of Water Pollution – Case Study on the Situation in Ipojuca River, Pernambuco, Brazil. *Water Air Pollut.* 180: 261-269.
- MMA (2005) [Resolução CONAMA nº 357](#) de 17 de março de 2005. 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. Publicação DOU: 18/03/2005.
- PNMA (2003) Atualização e complementação dos usos da água na bacia do Ipojuca river', Programa Nacional do Meio Ambiente, Recife, Brazil.
- SECTMA (2001): Plano Diretor de Recursos Hídricos da Bacia Hidrográfica do rio Ipojuca. Secretaria de Ciência Tecnologia e Meio Ambiente. Recife, SECTMA.
- SECTMA (2005). Secretaria de Ciência Tecnologia e Meio Ambiente (SECTMA). Relatório de monitoramento da qualidade da água da bacia hidrográfica do rio Ipojuca e reservatório de Tapacurá. Recife: CPRH, 2005. 33p.
- Sobral, M. C., Gunkel, G., Paes, R., Barros, A. M. L. & Figureida, R. C. B. (2008) Indicadores de qualidade da água: uma comparação entre os padrões estabelecidos pela Resolução Conama 357/05 e a pela Directiva Européia da Água – 2000/60/CE. *Brazilian Journal of Environmental Science and Tecnology – ICTR* (subm.)
- Sobral, M., Gunkel, G., S. Montenegro, J. Aureliano & A. C. Ferraz (2002) Evaluation of the Water Monitoring System for Tropical River Basins in Northeast Brazil. IWA Proceedings of the 9th International Specialised Conference on Watershed and River Basin Management. pp. 51-60.
- SRH (2002) Plano Diretor de Recursos Hídricos da Bacia do Ipojuca river. Secretaria de Recursos Hídricos SRH, Recife, Brazil, 3 Vol.
- Von Sperling, M. (2007): Estudos e modelagem da qualidade da água de rios. Departamento de Engenharia Sanitária e Ambiental; Universidade Federal de Minas Gerais. Belo Horizonte. 588 pp.

Acknowledgements

The authors express their thanks to Agência Estadual de Meio Ambiente e Recursos Hídricos (CPRH) for the data supply and support institutional and operational in this study and to Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq).