ECOTOX – Brazil

J. Braz. Soc. Ecotoxicol., v. 4, n. 1-3, 2009, 65-71
doi: 10.5132/jbse.2009.01.009

JBSE

Relationship Between Water Quality and Land use Along a Stretch of the Sorocaba River (SP)

A. M. DA SILVA*, A. H. ROSA, F. M. ANTUNES, D. P. NOGUEIRA & S. DA S. LESSA

Departamento de Engenharia Ambiental, Campus Experimental de Sorocaba – Universidade Estadual Paulista

(Received August 2, 2007; Accepted June 29, 2008)

ABSTRACT

Considering that the land use activities have direct impacts on water resources, the aim of this paper is presenting the spatial variation of the following parameters: pH, apparent color, true color, turbidity, conductivity and chemical oxygen demand along a stretch of the Sorocaba River, located in Sorocaba Municipality. Field incursions were done in order to survey in-situ the conductivity and pH. Water samples were collected and transported to the laboratory for analysis of the remnant parameters. Conductivity and chemical demand of oxygen were the parameters that more closely revealed the degradation of the water quality. It was verified that the urban region was the main responsible by degradation of water quality and that vegetation patches did not improve the water quality patterns, just estilizaded them. Thus, although the Sorocaba River has been trying to control its levels of contamination, an extended work must be done in order to get better the water quality and its surroundings.

Keywords: water contamination, water quality indicators, environmental analysis, Sorocaba River.

RESUMO

Qualidade da água e relações com o uso da terra no Rio Sorocaba (SP)

Considerando que o uso da terra causa impactos sobre a qualidade da água dos recursos hídricos, o objetivo deste trabalho é apresentar a variação espacial dos seguintes parâmetros: pH, cor aparente, cor verdadeira, turbidez, condutividade elétrica e demanda química de oxigênio ao longo de um trecho do rio Sorocaba, localizado no município de Sorocaba. Estes parâmetros foram investigados ao longo do Rio Sorocaba e também foi estudada a relação entre a variação das concentrações destes parâmetros e o uso da terra do município de Sorocaba. Visitas ao campo foram realizadas objetivando quantificar in situ a condutividade elétrica e o pH, além da realização de amostragem de água para posterior análise dos demais parâmetros em laboratório. Dentre os principais resultados, enfatiza-se que a condutividade elétrica e a DQO foram os parâmetros que melhor indicaram a degradação da qualidade da água. Foi verificado que a região urbana foi a grande responsável pela degradação da qualidade da água e que a presença de fragmentos de mata ciliar não melhorou os padrões de qualidade, apenas estabilizou. Apesar de o Rio Sorocaba ter atividades de despoluição, um extenso trabalho deve ainda ser desenvolvido para melhorar a qualidade da água deste rio e de sua bacia de drenagem.

Palavras-chave: contaminação hídrica, indicadores de qualidade da água, análise ambiental, Rio Sorocaba.

* Corresponding author: Alexandre Marco da Silva, e-mail: amsilva@sorocaba.unesp.br.

INTRODUCTION

Land use is in part determined by environmental factors such as soil characteristics, climate, topography, and vegetation. In turn, land use activities have direct impacts on water resources, while water quality and quantity greatly influence the sitting of land use activities (IHR, 1997).

Urbanization and industrialization processes constitute one of the main causes of degradation of the water quality and the water resources of a region. The health of a lotic ecosystem can be evaluated through many approaches (Wanielista et al., 1997). The survey and analysis of some physical and chemical variables regarding water quality (such as conductivity, pH, turbidity, color and chemical oxygen demand) have been one of the most typically used (Bellos; Sawidis, 2005).

In Brazil, studies aiming to investigate the relationships between land use and water quality are growing, mainly on the most industrialized regions (Martinelli et al., 1999; Silva; Sacomani, 2001; Brigante; Espindola, 2003, Silva et al., 2007).

The Sorocaba River, the most important water course of Sorocaba Municipality (São Paulo State, Brazil), has few studies about its water quality (Smith; Barrella, 2000; Silva et al., 2007; Smith et al., 2007), despite suffering expressive environmental impacts during the last decades. Thus, the spatial fluctuation of some water quality parameters and the possible influences of land use over these parameters were analyzed at Sorocaba River stretch localized in Sorocaba Municipality.

Study area

Sorocaba River (180 km long) sub-basin is located in the state of São Paulo, with a drainage area of 5,269 km² including 18 municipal districts. It is a subwatershed of the Tietê watershed and the Tietê River is a tributary of the Paraná River (Paraná River Basin). The Sorocaba River is formed by the rivers Sorocamirim and Sorocabuçu, and its main tributaries are the rivers Tatuí, Sarapuí, Pirajibu, and Ipanema (Smith et al., 2007). Annual average temperature is 21.4 °C and annual average rainfall height is 1,285 mm.

The total area is 456 km² with approximately 532,000 inhabitants, 98% of them living in urban settlements (Seade Foundation, 2006). For such studied site of the river the medium flow is 12.9 m³.s⁻¹, the lowest value is 11.8 m³.s⁻¹ for July and the highest value is 14.6 m³.s⁻¹ for February (Silva et al., 2007).

The main types of land use in the area of Sorocaba Municipality are shown in Figure 1 and Table 1. Table 1 also shows the distribution of the land cover categories specifically for the 30m buffer strip of the Sorocaba River. Pasture predominates in the whole area (36%), while natural remnant vegetation occurs in almost 70% of the 30 m buffer strip (riparian vegetation) (Table 1). However, almost all patches of riparian vegetation are located downstream of the urban region.

Sorocaba River is the main superficial water body of the city and it is currently highly impacted main due the discharge of both illicit untreated industrial and domestic sewages and

highly impacted riparian forest, especially in the urban area of Sorocaba Municipality (Silva et al., 2006).

MATERIAL AND METHODS

Twenty four samples of surface water (2,000 m apart from each other) were collected between February 14th and 15th, 2006 along the Sorocaba River from Votorantim Municipality (# 1) to the northwestern border of Sorocaba Municipality (# 24) (Figure 2). Site # 1 (Votorantim) was important in order to verify the chemical and physical situation of the water just before the water river arrives the Sorocaba Municipality.

The sampling activities were carried out on February 14th and 15th of 2006. Aboard the boat and using flasks and bottles, surface water samples were taken and were transported to the laboratory. Climatic conditions on these days did not preceded rainfall events.

The following parameters were measured: pH (with WTW 315i/SET portable pHmeter) and conductivity (with WTW 330/SET conductivimeter). In each sampling site 2.0 liters of water were sampled and transported at the laboratory in order to quantify apparent color, true color, and turbidity (expressed as Nephelometric Turbidity Units). All parameters were measured using a Hach DR/2000 Spectrophotometer. The chemical oxygen demand (COD) was also determined, through the oxide-reduction titrimetry, based on oxygen consumption during the chemical oxidation of the organic matter with potassium dichromate (open flux method, APHA, 1999).

The data set was organized in a worksheet and by using GIS software (ESRI, 1996) and a Landsat-5 georeferenced satellite image (May 16th / 2003); the Sorocaba River channel was on-screen digitalized. This digital file (vector/line format) was divided into twenty three parts 2000 m long, in order to integrate the dataset about the water parameters with the digital base about the Sorocaba River. The data set about each parameter was inserted using the "joint-table" command and the classes were defined using the "legend-editor" command of the software. Additionally, a Spearman correlation test was performed among some parameters (Ayres et al., 2000).

RESULTS AND DISCUSSION

The sampling sites and variation of each parameter along the Sorocaba River are summarized in Figure 2.

Table 1 – Relative occurrence of different types of land use in Sorocaba Municipality and along the 30 m buffer strip of Sorocaba River.

Type of land cover	Whole area	30 meters buffer strip (Sorocaba River)
Pasture	36.2%	7.5%
Natural Remnant Vegetation	22.1%	68.8%
Cultures	11.3%	4.9%
Urbanization	18.7%	15.2%
Bare Soil	10.9%	2.5%
Water bodies	0.8%	1.1%

Sources: data of whole area from Silva (2005) and data of 30 meters buffer strip from Silveira et al. (2006).

Figure 1 – Above: Location map of Sorocaba (Source: www.sorocaba.sp.gov.br). Below: Land cover along the Sorocaba municipality and river. Source: Silva et al. (2006).

The pH value was already high (slight alkaline) before the waters arrived the Sorocaba Municipality. Such high value was found for that sampling sites located in urbanized area. Between # 1 and 8, the value of pH decreased and downstream of the # 8 the pH values were even slightly acids. When the water passed through small urban settlements located in the lower part of the studied segment of the Sorocaba River, the values continued slight acids.

The lowest value was 6.7 (# 17) and the highest value was 7.8 (# 1), while the average value was 7.0. Comparatively, Smith & Barrella (2000), studying the relationships among some physical and chemical parameters and the ichthyofauna of the Sorocaba River and some marginal lagoons connected with the river, found pH values ranging from 6.7 to 7.5.

The conductivity values varied from $94 \mu\text{S}\cdot\text{cm}^{-1}$ (#1, the only one below $100 \mu\text{S}\cdot\text{cm}^{-1}$) to $169 \mu\text{S}\cdot\text{cm}^{-1}$ (#23). Values increased 52% between # 1 and 9, due to probable increasing in sewage inputs. Wang & Yin (1997) have seen a similar pattern for a temperate industrialized stream. After receiving pollution charges and passing through regions with good conditions of riparian vegetation, the values of conductivity did not decrease, but continued approximately stable in some parts of the river.

The smallest conductivity value was found in # 1 ($94 \mu\text{S}\cdot\text{cm}^{-1}$) and the highest value was found in # 23 ($169 \mu\text{S}\cdot\text{cm}^{-1}$). The average value was $143 \mu\text{S}\cdot\text{cm}^{-1}$, with a coefficient of variation of 12.8%. Comparatively Sousa & Tundisi (2000) found values ranging from 21 to $55 \mu\text{S}\cdot\text{cm}^{-1}$ for the Jacaré-Guaçu watershed and from 34 to $114 \mu\text{S}\cdot\text{cm}^{-1}$ for Jaú watershed (both meso-scale watersheds located in São Paulo State). On the other hand, Silva & Sacomani (2001) found in Pardo watershed (Botucatu Municipality, São Paulo State), values ranging from 18 to $688 \mu\text{S}\cdot\text{cm}^{-1}$. According to Silva & Sacomani (2001), this value expressively high may be due the presence of a sewage treatment station and due the limited effectiveness of treatment of this station, once they found organic residues in the water. These residues may have high concentrations of dissolved salts (Paul; Meyer, 2001; Silva; Sacomani, 2001).

Additionally, the possible increment in conductivity in urban streams may be attributed to both wastewater treatment plant effluent and non point source runoff (Paul; Meyer, 2001; Silva; Sacomani, 2001). Once treatment cannot remove all constituents from wastewater, treatment systems fail, and permitted discharge limits are exceeded. In Sorocaba River, there is the launching of water previously treated in the sewage treatment station. Such station is located between the # 7 and 8. These points presented, respectively, values 138 and $143 \mu\text{S}\cdot\text{cm}^{-1}$, showing an increasing less expressive than that one reported in Silva, Sacomani (2001).

The number of effluent between the sampling sites (spatial distribution of input sewages into the Sorocaba River) indicates that the highest concentration of number of effluents occurs between # 3 and 4 (part effectively urbanized). After these sites, a decreasing of effluents takes place. On one hand, in some sections of the river, the number of effluents maybe is not an expressive factor. On the other hand, the amount of sewage launched into the river in each point is the principal factor,

because the values of conductivity increases in some parts with small number of points of sewage input (Figure 3).

The chemical oxygen demand (COD) presented minimal value of $9.6 \text{ mg}\cdot\text{L}^{-1}$ and maximum value $31.2 \text{ mg}\cdot\text{L}^{-1}$. It was observed a diminution of the values in some parts located on lower region of the studied segment of the river (see intervals between # 16 – 17, 18 – 19 and 20 – 21, Figure 3). This fact is probably related with the existence of relicts of riparian vegetation in some parts of the river.

Since COD is an estimation of organic matter, it can be inferred that along the studied part of the Sorocaba River the discharge of non treated sewage (illicit) into the Sorocaba River might be occurring. Comparatively, for Mogi-Guaçu river basin, Brigante & Espindola (2003) registered COD values lower than that ones found on this study (the Mogi-Guaçu values ranged from 0 to $19 \text{ mg}\cdot\text{L}^{-1}$). The Mogi-Guaçu River is a mesoscale river basin and, although this river passes through a set of districts with high pollution potential (rural, domestic and industrial), Mogi-Guaçu River presented COD values lower than the Sorocaba River, possibly due the size of the river (the river flow of the Mogi-Guaçu is bigger than Sorocaba).

The values of the parameter “apparent color” ranged from 45 to 360 color units. Some parts of the river showed significant increase and others parts expressive diminution. The average value was 200 colors units. For true color the smallest value was 7 color unities (# 3) and the largest value was 21 color unities (# 14), while the average value was 15 color unities.

The correlation analysis performed between the apparent color and true color data sets revealed poor relationship ($r^2 = 0.24$, $p = 5\%$, $n=24$). In fact, comparing the maps of the Figure 2, it can be verified that the spatial variation between these two variables was different along the studied segment of the Sorocaba River. Only on the northern region of the investigated area (after # 15) the two variables presented both high values. For such region, according to consulted satellite image, lands located at the other side of the river belong to Iperó Municipality (rural area). Possible causes that justify the high values for both true and apparent color parameters is soil erosion and possible launching of non treated sewage came from small rural properties.

For turbidity, the lowest observed value was 6 NTUs (# 1) and the highest was 61 NTUs (# 8). A changeable performance of this parameter occurred along the studied segment of the river (Figure 2). There are parts of the river that, just after show high values of turbidity, the values decreased abruptly and increased again. One possible reason is the blending of contaminate water came from another stream (tributary) that caused this irregularity. Comparatively, Silva & Sacomani (2001) found values ranging from 5 to 62 NTUs for river whose waters passed by rural and urban areas.

Differently of the relation “apparent color x true color”, the correlation analysis between the variables “apparent color x turbidity” was significant ($r^2 = 0.95$, $n = 24$, $p = 1\%$), showing the expressive influence that the suspended solids have on the turbidity. Considering the season the sampling was carried out, Martinelli et al. (1999) state that an inverse correlation of the

Figure 2 – Spatial representation of the sampling sites and concentration range of the seven investigated parameters. Gray patches correspond to urban settlements.

Figure 3 – Spatial variability in conductivity ($\mu\text{S}\cdot\text{cm}^{-1}$), chemical oxygen demand ($\text{mg}\cdot\text{L}^{-1}$) and effluents inputs in the Sorocaba River.

variables with water discharge seems to be a common feature in most rivers, especially for conservative ions. For the present study, considering that the flow of the river is approximately 20% lower in the dry season than in the rainy season, it is expected that the Sorocaba River presents a worse situation in dry season (mainly between May and September).

Finally, it was observed that the land use of the buffer strip zone, at least currently, seems to have some influence over the water quality. However, the greatest influence was concerning the point sources (input of non-treated domestic and/or industrial sewage). The presence of riparian vegetation occurring predominantly along the lower part of the river (northern region of the Sorocaba Municipality), just stabilizes the effect of the values of some variables, but rarely decreases the value. In fact, as stated by Paul, Meyer (2001), the importance of riparian forests is reduced if the storm water system is designed to bypass them and discharge directly into the stream and if there is illicit discharge connections, leaking sewer systems, and failing septic systems, because they are large and persistent contributor of pollutants to urban streams.

According to engineering staff of the Municipal Service of Water and Wastewater of Sorocaba (personal communication), a significant part of the sewage of the Sorocaba Municipality is being already treated and two sewage treatment stations have been constructed in order to continuously diminish the discharges into the river. The combination of sewage treatment and reforestation of riparian zone seems to be the best way for restoration of the Sorocaba River.

CONCLUSION

The investigated parameters agreeably represented the close influence that the urbanization exerts over the quality of the Sorocaba River. Each parameter showed a peculiar performance along the investigated segment of the Sorocaba River.

The land use of the buffer strip zone, at least currently, seems to have some influence over the water quality. However, the greatest influence was regarding the point sources of non treated domestic and/or industrial sewage inputs, which should be focused for further treatment, for the sustainable

development and conservation of the aquatic wildlife of the Sorocaba River.

Acknowledgements – The authors are grateful to FAPESP (grants 04/13096-7 and 03/13044-4) and to CNPq by financial support and scholarships (PIBIC/CNPq). The authors are also grateful to Environmental Police of Sorocaba (Mr. Cap. Paulo Roberto de Oliveira), by the logistic support (availability of use of boat and others equipments).

REFERENCES

- APHA (AMERICAN PUBLIC HEALTH ASSOCIATION), 1999, *Standard Methods for the Examination of Water and Wastewater*, 20th edition. Water Environment Federation, USA, 2, 384 p.
- AYRES, M., AYRES Jr., M., AYRES, D. J. & SANTOS, A. S., 2000, *BioEstat 2.0 – aplicações estatísticas nas áreas das ciências biológicas e médicas*. Belém – PA, Soc. Civil Mamirauá/CNPq, 259 p.
- BELLOS, D. & SAWIDIS, T., 2005, Chemical pollution monitoring of the River Pinios (Thessalia – Greece). *J. Environ. Manage.*, 76: 282–292.
- BRIGANTE, J. & ESPÍNDOLA, E. L. G., 2003, *Limnologia Fluvial – um estudo no Rio Mogi-Guaçu*. Rima Editora – São Carlos – SP, 260 p.
- ESRI (ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE), 1996, Arcview GIS – The Geographic Information System for Everyone. Version 3.1 – User's Manual, 350 p.
- MARTINELLI, L. A., KRUSCHE, A. V., VICTORIA, R. L., CAMARGO, P. B., BERNARDES, M., FERRAZ, E. S., MORAES, J. M. & BALLESTER, M. V., 1999, Effects of sewage on the chemical composition of Piracicaba River, Brazil. *Water Air Soil Pollut.* 110: 67-79.
- PAUL, M. J. & MEYER, J. L., 2001, Streams in the urban landscape. *Ann. Rev. Ecol. Evol. Syst* 32: 333-365.
- SEADE FOUNDATION, 2006, (Date of consulting). *Informações municipais*. Website: www.seade.sp.gov.br.
- SILVA, A. M., 2005. Cobertura do solo do município de Sorocaba-SP e implicações na fragmentação dos remanescentes florestais. *Rev. Est. Ambientais*, 7: 38-46.
- SILVA, A. M., ROSA, A., LOURENÇO, R. W., GOUVEIA, D. & BELLIN, I., 2006, Uso da terra, processos erosivos e impactos na qualidade da água do rio Sorocaba, Sorocaba, SP – Brasil. *IV Congresso Íbero-americano de Física e Química ambiental*, Cáceres – Spain, 343-350.
- SILVA, A. M., ROSA, A. H., SILVEIRA, F. M., VAZ, S. S. & OLIVEIRA, G. S. 2007. Input and output rates of some chemical solutes in Sorocaba River. *Rev. Est. Ambientais*, 9: 16-26.
- SILVA, A. M. M. & SACOMANI, L. B., 2001, Using chemical and physical parameters to define the quality of Pardo River water (Botucatu, SP – Brazil). *Water Res.*, 35: 1609-1616.
- SILVEIRA, F. M., NOGUEIRA, D. P., IKEMATSU, P, PAULA, F.P. & SILVA, A.M., 2006, Análise da ocorrência de vegetação natural em quatro larguras de faixa “buffer” no rio Sorocaba – SP. *Abstracts of the 14th SIICUSP*, Piracicaba – SP. CD-rom.
- SMITH, W. S. & BARRELLA, W., 2000, The ichthyofauna of the marginal lagoons of the Sorocaba River, SP, Brazil: composition, abundance and effect of the anthropogenic actions. *Braz. J. Biol.*, 60: 627-632.
- SMITH, W. S., PETRERE JR, M. & BARRELLA, W. 2007, Fish, Sorocaba river sub-basin, state of São Paulo, Brazil. *Check List*, 3: 282-286.
- SOUSA, A. D. G. & TUNDISI, J. G., 2000, Hidrogeochemical comparative study of the Jaú and Jacaré-Guaçu river watersheds. *Braz. J. Biol.*, 60: 563-570.
- WANG, X. & YIN, Z., 1997, Using GIS to assess the relationship between land use and water quality at a watershed level. *Environ. Int.*, 23: 103-114.
- WANIELISTA, M., KERSTEN, R. & EAGLIN, R., 1997, *Hydrology: water quantity and quality control*. John Wiley & Sons, London, 2nd Edition, 567 p.