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The Importance of Watershed Studies: the Cintra Stream Micro-Watershed Model

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Abstract

Water quality in the Cintra Stream micro-watershed was assessed by means of analyses during 2 periods (June/2005-May/2006 and January/2007-December/2007), using bimonthly collections at 8 different sites, for the physical and chemical variables pH, NO_3^-, NO_2^-, BOD_5, DO and TOC. This work aimed to study the anthropogenic effects on the Cintra Stream and their interrelations with soil occupation, polluting sources, water use and contributions to the water quality of two large bodies of water: the Tietê River and the Guarani Aquifer. To study the variables, variance analyses were followed by Tukey's test, at a 5% significance level. All studied parameters indicated that the stream shows self-depuration capacity starting at site 3 due to dilution, oxygenation of the water and consequent biodegradation of the existent organic matter. Corrective measures at sites 1 and 2 followed by preventive actions in agricultural areas (S_3 to S_7) will permit use of the stream water in the rural area.

Key words: micro-watershed, Cintra stream, Tietê river, Guaraní aquifer, physicochemical parameters.

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Importancia del estudio de las cuencas hidrográficas: una microcuenca modelo del arroyo de Cintra

Resumen

Fue evaluada la calidad del agua de la cuenca del arroyo de Cintra a través de análisis en 2 periodos (junio/2005 a mayo/2006 y enero a diciembre/2007), con colectas bimestrales en 8 puntos distintos con las variables físicas y químicas pH, NO_3^-, NO_2^-, DBO_5, OD y COT. Este trabajo se propuso estudiar los efectos antropogénicos en el arroyo de Cintra y sus interrelaciones con la ocupación del suelo, fuentes contaminantes, uso del agua y contribuciones para la calidad de las aguas de dos grandes cuerpos de agua: Río "Tietê" y Acuífero "Guaraní". Para analizar las variables, fueron realizadas análisis de varianza seguidas del Test de Tukey, con un nivel de significancia de $p < 0{,}05$. Todos los parámetros estudiados demostraron la capacidad de autodepuración del arroyo a partir del punto 3 debido al efecto de dilución, oxigenación del agua y consecuente biodegradación de la materia orgánica existente. Medidas correctivas en los puntos 1 y 2, seguidas de acciones preventivas en áreas agrícolas (del P_3 al P_7) posibilitarán el uso del agua del arroyo en el área rural.

Palabras clave: microcuenca hidrográfica, arroyo de Cintra, Río "Tietê", Acuífero "Guaraní", parámetros físico-químicos.

1. Introduction

Tietê River is the most important water course in São Paulo State-Brazil, constituting a model of multiple use of water resources in this country, based on the model of Tennessee River-USA [1]. Tietê River rises in "Serra do Mar", Salesópolis Municipality, at 1030 meters altitude, 22 km away from the Atlantic beaches. Differently from other rivers, it runs towards the interior of São Paulo State in a 1140 km course from its source to Paraná River, in the borderline of Mato Grosso do Sul State [2]. As this river passes São Paulo City, one of the largest cities in the world, it becomes one of the most contaminated rivers in the planet. Thus, São Paulo City is considered the worst villain in the degradation of this important water resource, concentrating the attention. However, most rivers of Tietê Watershed are responsible for the most intense erosive action and are victims of residential and industrial polluting sources in the municipalities. According to Zanela [3], it is no use preserving large rivers like Tietê without monitoring its effluents; thus, studies and the control of the contribution of watersheds are needed to avoid intensifying the degradation of Tietê River Watershed.

The micro-watersheds in Botucatu Municipality, São Paulo State, Brazil, may contribute to intensify the degradation of Tietê River Watershed. Valente et al. (4) studied the pollution in Botucatu Municipality by sanitary sewage released "in natura" into Lavapés Creek (Medium Tietê Watershed) and concluded that, in addition to making water use unfeasible in the creek's course, it contributes to worsen the eutrophication at Barra Bonita Dam. Ten years later, with the beginning of sewage treatment, Silva et al. (5) demonstrated the improved water quality at this creek and the lower impact at its surroundings downstream to that municipality.

Botucatu Municipality is located in the central-south region of São Paulo State, with a territorial area of 1522 km^2, at 230 km away from the State capital, São Paulo City.

The surface waters in Botucatu Municipality are drained by two watersheds, that of Paranapanema River and the one of Tietê River, both rivers are effluents of Paraná River, integrating, continentally, Platina Watershed.

In Botucatu Municipality, Cintra Stream, the study object in this work, is an effluent of Araquá River and is located in Araquá Micro-watershed, both running to Barra Bonita Reservoir (Tietê River). This stream rises in the

Botanical Garden inside the campus of São Paulo State University-UNESP, in Rubião Junior. Between its source and the waterfalls located in Pavuna Ecological Park (7.3 km), the stream is influenced by the effluent treated in the stabilization lagoons of the Wastewater Treatment Plant-Basic Sanitation Company of São Paulo State (WTP-SABESP) for the treatment of sanitary sewage from the population at Rubião Junior District, Clinical Hospital Units, Research laboratories of the Institute of Biosciences and Veterinary Hospital, and areas of pasture, orchards and animal consumption, as well as regions without riparian forest.

Cintra Stream has regional importance in agriculture, animal consumption, irrigation, domestic use, recreation and leisure. Its waters affect the quality of the micro-watershed of Araquá, a tributary of Barra Bonita Hydroelectric Dam (Tietê River). Thus, Cintra Stream, located in Tietê Watershed, contributes to the water quality in Tietê River which in this region is recovered from the pollution caused by the wastes from São Paulo City.

In the region of Botucatu, Cintra Stream probably contributes to the water quality in Guarany Aquifer, one of the major subterranean water reservoirs in the world, considering it is situated in the aquifer reload zone [6].

This Aquifer, dated between 245 and 144 million years ago, is the most important natural reservoir of subterranean waters in the planet and occupies an area of 1088 million Km^2, with 1500 meters depth, temperature of up to 65°C, constant water volume of the order of 45 thousand Km^3, extending over the territories of Uruguay, Argentina and Paraguay [3].

Guarany Aquifer is considered extremely important in Botucatu region since it is a zone of reload and outcrop of aquiferous geological formations in the west of São Paulo State [7].

Thus, the present work aims to study the anthropogenic effects on Cintra Stream and its interrelations with soil occupation, polluting sources, water usage and contributions to the water quality in two great compartments: Tietê River and Guarani Aquifer.

2. Material and Methods

The analyses were carried out in the Department of Chemistry and Biochemistry, Institute of Biosciences, São Paulo State University-UNESP, Botucatu Campus. Collections were done in Cintra Stream Micro-watershed (Figure 1) which is located to the northwest of Botucatu City and rises inside UNESP Campus, in Rubião Junior,

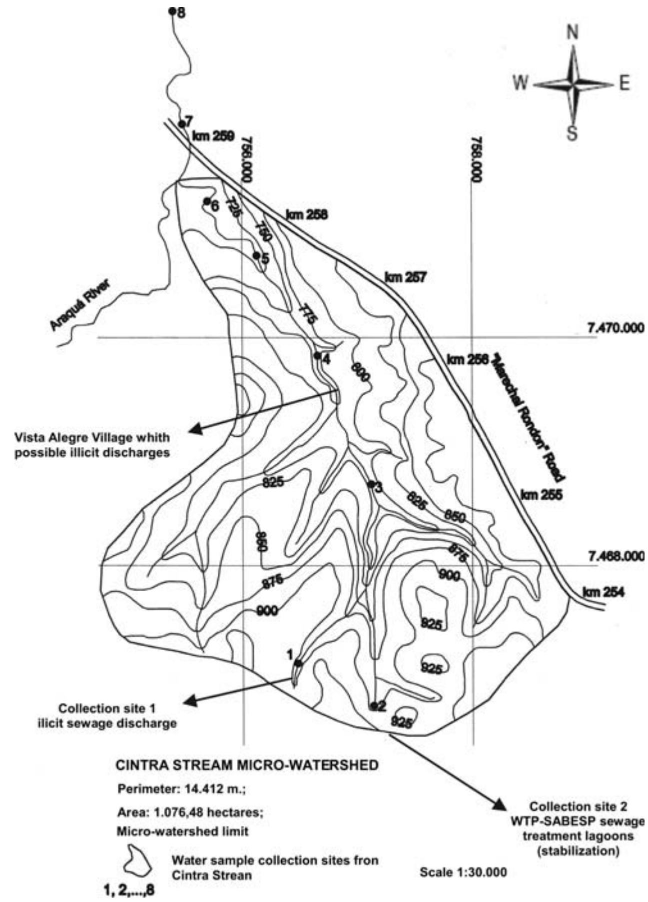

Figure 1. Cintra Stream Micro-watershed.

running towards the north until Barra Bonita Dam (Tietê River). The water was analyzed at 8 different sites along this water course; 6 collection sites (S_1 to S_6) are inside this micro-watershed and 2 of them (S_7 and S_8) are downstream to its mouth, which is a water divisor in Araquá River Micro-watershed, where Pavuna Ecological Park and its waterfalls are located.

The criteria for choosing such sites were the contributions of drainage subwatersheds of Cintra Stream main tributaries, relative to the anthropic actions of urban and/or rural populations, besides their physical conditions and easy access (Table 1).

The total area of Cintra Stream Micro-watershed is 1.076.48 ha and as regards soil use and occupation there is predominance of pasture area (54.45%), followed by plantation areas (16.83%), natural vegetation (14.46%), and areas of human occupation. Such data were obtained through the Digital Planimetry System [8]. Samples were collected from June/2005 to May/2006 (period 1) and from January to December/2007 (period 2), according to a bimonthly collection chronogram.

Table 1. Description of the collection sites in the study area.

Collection sites	Location	Distance from the source (m)	Altitude (m)	Natural vegetation	Plantation Area	Soil conservation
S_1	Downstream to the source	225	851	Absent	Gardening	Absent
S_2	Downstream to the stabilization lagoon	616	832	Absent	Reforestation	Present
S_3	Upstream to Vista Alegre Village	2,061	785	Present	Agriculture and orchards	Present
S_4	Downstream to Vista Alegre Village	3,305	763	Absent	Agriculture and pastures	Present
S_5	Boa Esperança Land Parcel	4,327	757	Absent	Agriculture, Pasture, houses	Present
S_6	Close to Mar. Rondon Highway Km 258	5,102	741	Absent	Agriculture and pastures	Present
S_7	Close to Mar. Rondon Highway Km 259	6,098	734	Absent	Agriculture and pastures	Present
S_8	Environmental Protection Area (EPA)	7,280	616	Present	Absent	Present

The methods adopted to determine physicochemical parameters were those recommended by the Standard Methods for the Examination of Water and Wastewater [9]. The potential of Hydrogen (pH) was determined with a pHmeter (Hanna Instruments, model HI 221). Electrical conductivity (EC) was assessed using a conductivimeter (Hanna Instruments, model HI 2300). Biochemical oxygen demand (BOD) was determined through the 5-day incubation method and Dissolved Oxygen (DO) through the method of Winkler, modified with sodium azide. Total Organic Carbon (TOC) in the waters was assessed using the non-purgable organic carbon (CONP) method and TOC analyzer (Shimadzu, model TOC-v CPH/CPN). Nitrite (NO_2^-) and nitrate (NO_3^-) determination is based on the diazotization by the reaction of Griess-Ilosvay between nitrite and -naphthylamine, N-(1-naphthyl) ethylenediamine conjugated to sulfanilamide, and was performed through spectrophotometry, according to Taras [10], Rodier [11], Williams [12], Golterman et al. [13] and Crompton [14].

The parameters were analyzed at all sites, except for BOD which was evaluated only at sites 1; 2; 4 and 8, chosen due to the characteristics of the influence areas: S_1 receives non-treated sewage; S_2 receives WTP-SABESP treated effluent; S_4 is close to Vista Alegre Village, considering possible illegal discharges; and S_8 presents agricultural and pasture areas located upstream (Figure 1).

To verify the behavior of each variable at the sites, analyses of variance were followed by Tukey's test (Tukey's Studentized Range-HSD) at 5% significance level [15].

3. Results and Discussion

The mean results of the evaluated physicochemical parameters are shown in Table 2. Considering the statistical treatment for each site, pH mean values significantly differed in amplitude at S_1 and S_2, relative to the remaining sites, in all collections in the two periods. At these two sites, pH was slightly acid with means ranging from 6.90 to 6.89 probably due to the higher organic matter content under decomposition (CO_2 generation and carbonic acid formation) [16].

From S_3 to S_8, pH mean values ranged from 7.51 to 7.96 in the two periods and did not statistically differ (Table 2) due to the alkaline chemical reactions along the course possibly influenced by agricultural and pasture regions, except at S_3 and S_8. As regards soil occupation in the micro-watershed (S_1 to S_6), there is predominance of pasture, followed by natural vegetation and agriculture. Natural area prevails at S_3 and S_8 surroundings (Figure 1).

Rainfall index significantly varied in the two study periods. In period 1, rainfall exceeded 150 mm in the collections of January and March 2006, whereas in period 2 rainfall was high only in December 2007. Such data were obtained from the Department of Natural Resources/Environmental Sciences, College of Agronomical Sciences, UNESP, Botucatu. The measured parameters were not significantly influenced by rainfall since a drought period of 5 days before collections was respected in order to not compromise the environment natural condition due to rain water dilution. There was no significant water course flow variation.

Table 2. Results of the Tukey's test for the variables pH, electrical conductivity (EC), nitrate (NO_3^-), nitrite (NO_2^-), total organic carbon (TOC), biochemical oxygen demand (BOD_5) and dissolved oxygen (DO) at the collection sites in the study area.

Site	pH	EC $\mu S.cm^{-1}$	NO_3^- ($mg.L^{-1}$)	NO_2^- ($mg.L^{-1}$)	TOC ($mg.L^{-1}$)	BOD_5 ($mgO_2.L^{-1}$)	DO ($mgO_2.L^{-1}$)
S_1	6.900B	74.83C	0.48B	0.011B	37.178A	15.14A	3.83C
S_2	6.896B	181.92A	2.86A	0.259A	23.005AB	4.84B	5.22C
S_3	7.519A	128.20B	2.04B	0.06AB	17.590AB	-	7.17B
S_4	7.573A	103.20BC	1.13B	0.029B	16.221B	2.07C	7.16B
S_5	7.435AB	95.93BC	0.90B	0.014B	14.701B	-	6.78B
S_6	7.556A	83.98BC	0.65B	0.008B	15.373B	-	7.25AB
S_7	7.591A	78.85C	1.52B	0.008B	12.789B	-	7.82AB
S_8	7.960A	76.72C	0.59B	0.006B	13.979B	1.07C	8.53A
F value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0069	<0.0001	<0.0001

Means followed by the same letter do not differ statistically.

Analyzed separately in the two periods, pH profile presents significant variation (Figure 2). Between S_3 and S_7, values kept constant in each period, and at S_8, although not varying statistically, values significantly differed. S_8 is located on the bottom of the waterfall, where there is water impoundment (lentic environment) and possible accumulation of alkaline species carried over the stream, mainly those originated from agricultural areas (S_3 to S_7). At S_8, pH might have increased due to its localization in the Basaltic Cuesta (EPA), where the stream runs over the basalt slabs. According to Araujo et al. [17], the original soil in Botucatu Municipality is basalt "metáfiro" and probably diabasic (eruptive basaltic); however, Leinz and Amaral [18] stated that the terms acid, basic and neutral for the rocks do not correspond to their respective chemical character. On the other hand, Press et al. [19] reported that the rocks undergo a very slow process of chemical weathering or a chemical alteration followed by physical weathering, in which the particles formed due to the mechanical disaggregation chemically alter the environment. In basaltic rocks, silicates are weathered in the presence of water through hydrolysis, becoming more alkaline.

EC mean value was high at S_2 (181.92 $\mu S.cm^{-1}$) in the two periods (Table 2) due to discharge of the effluent treated and mineralized in the stabilization lagoon. The highest mean value was 128.2 $\mu S.cm^{-1}$ as it is the first site that receives the effluent mineralized and concentrated in the lagoon, and the lowest value was 74.83 $\mu S.cm^{-1}$ (Table 2) due to the dilution caused by the tributaries observed in Figure 1. The dilution effect can also be observed in Figure 3. EC peak was recorded at S_2; at the remaining sites, mean values gradually decreased with the distance

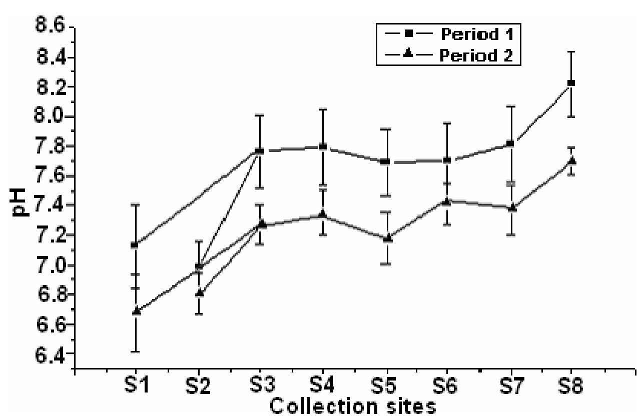

Figure 2. pH profile at the collection sites in the study area.

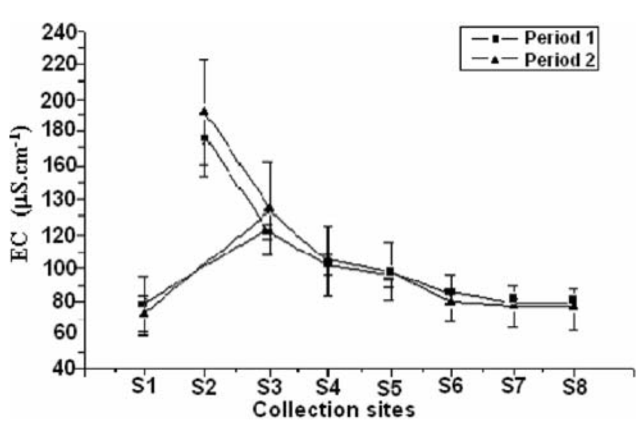

Figure 3. Electrical conductivity (EC; $\mu S.cm^{-1}$) profile at the collection sites in the study area.

from the sources of dissolved salts (S_1 and S_2), although organic matter mineralization, at lower concentration, continues in the course. Similarly, Psilovikos et al. (20) noted that low EC values coincided with high water levels at Nestos River (Bulgaria) and the opposite occurred even with organic matter discharge, which justifies its dilution.

Analyzing EC and rainfall index together, differences were not significant in the two periods. Souza [21] studied the quality of the effluent treated in the WTP-SABESP, located downstream to S_2 in the present study, and observed that there was no significant EC variation in relation to humid and dry periods. Figure 3 also indicates that the values in the two periods were very close; they were slightly but not statistically different.

The mean NO_3^- variation between the two periods was statistically different only at S_2 (2.86 mg.L^{-1}), as shown in table 2. NO_3^- mean values gradually decreased from S_2 to S_8 in the two periods, except for S_7 in Figure 4.

The effluent treated in the stabilization lagoons is discharged into Cintra Stream with a relatively high NO_3^- concentration, 2.86 mg.L^{-1}, at S_2 due to the degradation of the organic matter concentrated in the treatment system. Such concentration decreases downstream due to the water course dilution effect, in addition to the contribution of other tributary rivers (Figure 1) and, at S_8, the concentration falls to 0.59 mg.L^{-1}. Differently from S_2, S_1 presented low NO_3^- concentration (0.48 mg.L^{-1}), on average equal to that at S_8. This occurs because there is not a retention time of the illegal sewage for predegradation before discharged at S_1. The polluted water at S_1 immediately flows to S_3 where it meets the waters from S_2 and is degraded downstream.

S_7 is located in an area of agriculture and irrigation, where nitrogen residues of agrochemical origin were discharged at the collection period. Chattopadhyay et al. [22] verified that intensive agriculture and the use of nitrogen fertilizers cause a nitrate increase in dry and humid seasons. As shown in Figure 4, S_2 and S_7 represent high nitrate levels since they statistically differ in the two periods, relative to the remaining sites.

The mean NO_2^- variation between the two periods statistically differed only at S_2 (0.259mg.L^{-1} in N), as indicated in Table 2. NO_2^- concentration was similar among S_1, S_5, S_6, S_7 and S8 (Figure 5). The high NO_2^- content at S_2 in the two periods was punctual due to the organic load variation. The same was observed for NO_3^- content, which tended to become close to that of NO_2^- in the two periods at all sites, except for S_2 and S_7.

NO_2^- concentration decreased due to the high water oxygenation resultant from the photosynthesis process in

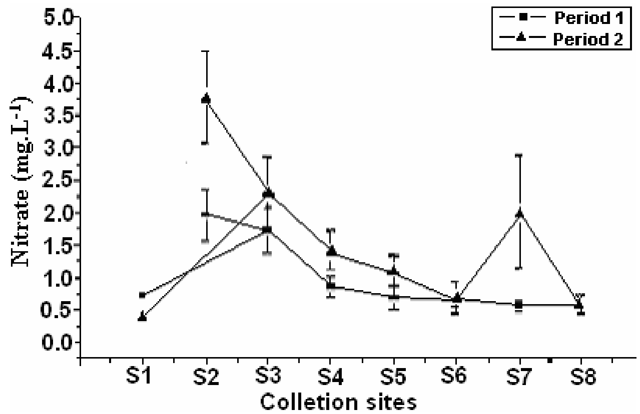

Figure 4. Nitrate (NO_3^-) profile at the collection sites in the study area.

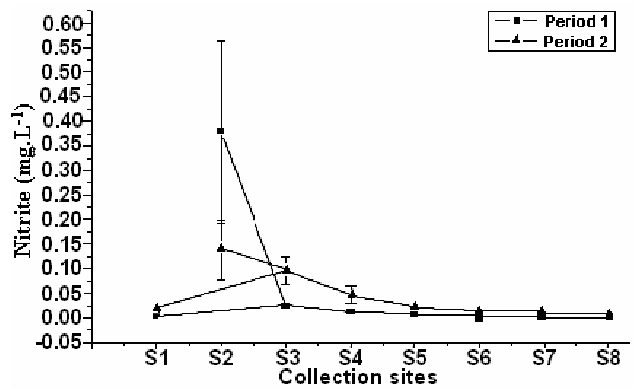

Figure 5. Nitrite (NO_2^-) profile at the collection sites in the study area.

the stabilization lagoon and from the stream lotic system as there is a sharp declivity of 235 m unevenness from the source to the mouth (Table 1).

As seen in Table 2, DO mean concentrations were low at S_1 and S_2 (3.83 and 5.22 mgO_2.L^{-1}, respectively) due to the relatively high TOC concentration (Figure 7). From S_3 to S_7, mean DO values increased and did not significantly vary due to TOC stabilization until S_8. TOC decrease is due to the degradation downstream, which causes oxygen demand and dilution in the course. The significant increase in DO concentration at S_8, relative to S_7, was due to a fall in altitude of around 110 m, as well as to a waterfall upstream to S_8 (Figure 6). Oxygen solubilization in the waters is higher at the sea level (higher atmospheric pressure); the higher the altitude, the lower the oxygen solubility (lower pressure). Oxygen solubility also depends on the temperature: the lower the temperature, the higher the solubility. The introduction of oxygen into the water course is proportional to the water turbulence degree [16].

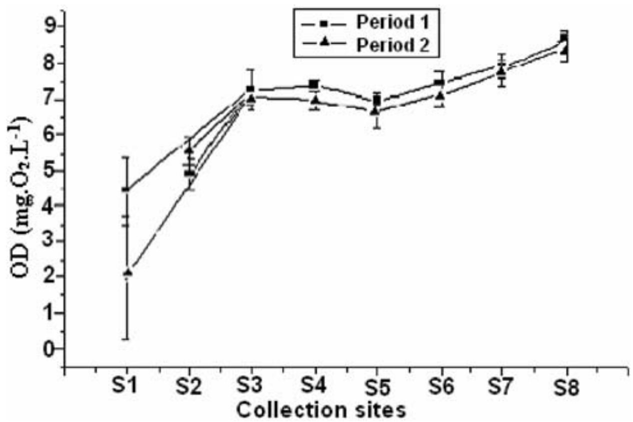

Figure 6. Dissolved oxygen (DO; mg.O_2.L^{-1}) profile at the collection sites in the study area.

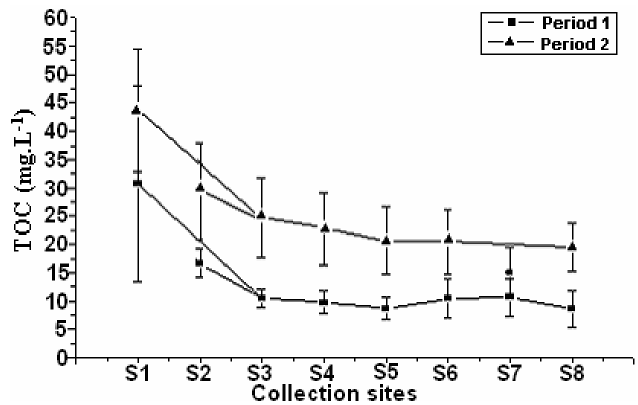

Figure 7. Total organic carbon (TOC; mg.L^{-1}) profile at the collection sites in the study area.

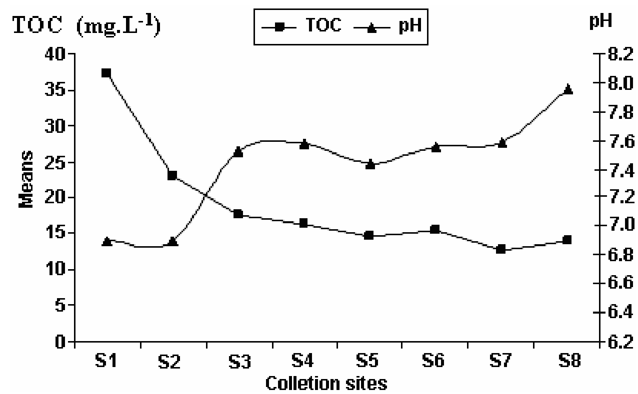

Figure 8. Spatial variation of mean concentrations of total organic carbon (TOC; mg.L^{-1}) and pH at the collection sites in the study area.

DO increase –downstream, for levels close to saturation– is the main responsible for the great autodepuration capacity of this water course. DO reposition is favored by the currents and waterfalls, which mechanically introduce oxygen from the air, as well as by the increase in oxygen solubility due to the pressure increase (lower altitude downstream).

TOC concentrations are relatively high at S_1 and S_2 but rapidly decrease through autodepuration and dilution, as shown in Figure 7, keeping practically stable from S_5 in period 1 and at S_4 in period 2.

There was a significant interaction between TOC and pH (Figure 8) since, according to Nuvolari et al. [16], the higher the organic load (TOC), the lower the pH due to the byproducts of the respiratory process of microbial degradation and CO_2 release, converting carbonic acid into water. The inverse is observed when concentrations are lower (S_3 to S_8) and pH gradually increases. Alkaline pH at distant contamination sites (S_1 and S_2) is also influenced by alkaline species carried from the soil used for agriculture to the stream, besides alkaline species characteristic of the soil in the region.

BOD_5 mean (Table 2) at S_1 (period 2) was around 15.14 mgO_2.L^{-1} (40.7% relative to the oxygen demand of TOC). This indicates that there is a considerable introduction of biodegradable organic matter at this site and that around 40% of the organic matter is non-biodegradable or of difficult biodegradation. BOD_5 had low results from TOC stabilization, indicating that the greatest part of the remaining matter was non-biodegradable or of difficult biodegradation for both periods. O_2 biochemical demand was lower at S_8 (mean 1.07 mgO_2.L^{-1}), i.e. there was lower TOC concentration (Figure 8).

The concept of water quality monitoring is much wider than the simple verification of the legal patterns of water quality. It must fulfill the need of response to the alteration and the reasons why such changes occur [23]. There are many involved variables and the response of the watershed according to the water quality aspect of several processes that occur in its surface has a highly expressive degree of randomness [24]. In the present study, the studied variables revealed Cintra Stream water is contaminated. Thus, there is a range of discussions on the contribution and effects of such waters on Tietê River and Guaraní Aquifer. On one hand, Tietê River is compared with the characteristics of Mississipi River in the USA, due to its multiple uses which require high water quality. On the other hand, the existence of vulnerable reload areas in Guaraní Aquifer, in Botucatu's Cuesta front must be considered; these areas may be contaminated by micro-watersheds and streams like Cintra in the interior of this immense subterraneous reservoir of drinking water, which may contribute to a cumulative contamination, causing future problems.

The significant decrease in the concentration of physicochemical parameters as Cintra becomes closer to its mouth, due to the autodepuration and dilution effect, is positive but impairs the use of water upstream, causing cumulative damages to this water course.

4. Conclusion

Considering the parameters evaluated in 2 study periods, Cintra Stream does not contributes to the water quality worsening in Tietê River Watershed. Cintra Stream has a great autodepuration capacity due to the high declivity between its source and mouth, which leads to the presence of currents and several waterfalls. The water quality in Cintra mouth is recovered due to autodepuration and dilution effect. However, between sites 1 and 2, water usage is not possible for livestock (animal consumption). The parameters TOC, EC, BOD and DO indicated a rapid autodepuration in this stream. The parameter Electrical Conductivity indicated a dilution effect on the decrease of polluting inorganic compounds and, due to organic matter mineralization, almost reduced to the spring level at the last evaluated site (S_8). The parameter nitrogen (nitrate) allowed the identification of the diffuse source of pollution by fertilizers in the rural zone, at S_7. pH values were almost stable between sites 3 and 7 and we could not conclude whether the increase at S_8 was due to the anthropogenic activities or caused by a geological problem at this site. The subterranean waters of Guarani Aquifer constitute a system susceptible to contamination. Thus, the environmental preservation of the reload zone of such aquifer through water quality control in the rivers is important to assure the public supply of hundreds of cities of median and large sizes using wells of different depths. Therefore, corrective actions at critical sites of effluent discharge (S_1 and S_2), recovery of the riparian forest over the stream, use and occupation of the soil, together with continued education of farmers through the establishment of an agroecological system, as well as stimulation of organic management or conservative practices will improve water quality in this stream.

References

[1] PIMENTEL, J.B.O., MORAES, M.B. (2007). Fundo Catullo Branco: The challenges in the development of the archival organization. Patrimony and memory (in Portuguese). **UNESP FCLAs CEDAP,** 3(1), 1.

[2] SOUZA, A.J., ANDRADE, F.C., DI PIERI, J.C., TOLEDO PIZA, M.A.B., CONTE, M.L. (2003). Physical aspects of Botucatu Municipality, São Paulo State, Brazil (in Portuguese). **Rev. Ciência Geogr.** 9(1): 54-75.

[3] ZANELA, J. (2008). Guaraní Aquifer will have a new map (in Portuguese). **UNESP's 373 newspaper,** São Paulo, Brazil, year 22, n. 235. p.16.

[4] VALENTE, J.P.S.; PADILHA, P.M.; SILVA, A.M.M. (1997). Contribution of Botucatu Municipality, São Paulo State, Brazil, with nutrients (phosphorus and nitrogen) to the eutrophication at Barra Bonita Dam, **Ecl. Quím** (**São Paulo**) 22: 31-48.

[5] SILVA, F. A.; TRAFICANTE, D. P.; NEVES, R. C. F.; FLORENTINO, A. O.; CHINELATO, F. C. S.; BICUDO, R. VALENTE, J. P. S. (2007) New water quality profile at Lavapés Creek after sewage treatment in Botucatu Municipality, São Paulo State, Brazil. **XLVII Brazilian Meeting on Chemistry,** 2007. no. 267. CD.Theme: Non-renewable resources. Natal, Rio Grande do Norte State, Brazil.

[6] FRASÃO, L. (2009). Brazil discusses with its neighbors the rational use of the super reservoir. Partnership on Guarani Aquifer is the main issue of the Water Forum (in Portuguese). O Estado de SÃO Paulo. March 22, 2009, H2.

[7] ALMEIDA, F.F.M. (1954). Botucatu, a Triassic desert in South America (in Portuguese). Notas Preliminares e Estudos-Divisão de Geologia e Mineralogia. 86, 21.

[8] SILVA, C.M., CATÂNEO, A., CARDOSO, L.G. (1993). Digitized planimetry system (in Portuguese). In: **XXIII Jornada Científica da Associação dos Docentes.** UNESP, Faculdade de Ciências Agronômicas, Botucatu, pp. 217-217.

[9] GREENBERG, A.E., RICE, E.W., ClESCERI, L.S., EATON, A.D. (2005). **Standard methods for examination of water and wastewater.** American Water Works Association and Water Pollution Control Federation, Washington, 1368 p.

[10] TARAS, M.J. (1958). Nitrite. Nitrate. In: Boltz, D.F. (Ed.). **Colorimetric determination of nonmetals.** Interscience, New York, pp. 124-160.

[11] RODIER, J. (1975). Analysis of natural waters. Chemical pollution indicators: nitrites; anions: nitrate. In: Rodier, J. **Analysis of water.** Halsted, New York. pp. 123-127, 163-169.

[12] WILLIAMS, J.W. (1979). **Handbook of anion determination.** Butterworths, London, pp. 119-53.

[13] GOLTERMAN, H.L., CLYMO, R.S., OHNSTAD, M.A.M. (1991). **Methods for physical and chemical analysis of freshwaters.** Blackwell Scientific Publications, Oxford, 2178 p.

[14] CROMPTON, T.R. (1996). Nitrogen-containing anions: nitrate and nitrite. In: Crompton, T.R. **Determination of anions.** Springer, Berlin. 217-241.

[15] SOKAL, R.R., ROHLF, F.J. (1995). **Biometry: The principles and practice of statistics in biological research.** W.H. Freeman, New York, 887 p.

[16] NUVOLARI, A., TELLES, D.A., RIBEIRO, J.T., MIYASHITA, N.J., RODRIGUES, R.B., ARAUJO, R. (2003). **Sanitary sewer, transport, treatment and agricultural reuse** (in Portuguese). Edgard Blücher, São Paulo, 505 p.

[17] ARAUJO Jr., A.A., CAMPOS S., BARROS Z.X., CARDOSO L.G. (2002). Physical conservation diagnosis of ten watersheds of Capivara River aiming a rational soil occupation (in Portuguese). **Irriga** 7(2): 106-121.

[18] LEINZ, V., Amaral, S.E. (1980). **General geology** (in Portuguese). Companhia Editora Nacional, São Paulo, 397 p.

[19] PRESS, F., GROTZINGER, J., SIEVER, R., JORDAN, TH. (2006). **To understand the Earth** (in Portuguese). Bookman, Porto Alegre, 656 p.

[20] PSILOVIKOS, A., MARGONI, S. & PSILOVIKOS, A. (2006). Simulation and trend analysis of the water quality monitoring daily data in Nestos river delta. Contribution to the sustainable management and results for the years 2000-2002. **Environ. Monit. and Assessm.** 116:543-562.

[21] SOUZA, I.F. (2005). Characterization of the quality of effluents and the possible utilization of the biomass as energy source (in Portuguese). Thesis (Masters in Agronomy “Energy in Agriculture”), São Paulo State University, Botucatu, São Paulo State, Brazil, 127 p.

[22] CHATTOPADHYAY, S., ASA RANI, L.A., SANGEETHA, P.V. (2005). Water quality variations as linked to landuse pattern: A case study in Chalakudy river basin, Kerala. **Current Science** 89 (12): 2163-2169.

[23] BRASIL. National Council for the Environment (CONAMA). CONAMA Resolution number 357 of March 17, (2005), about the classification of water bodies and direction for its fitting, as well as the establishment of conditions and patterns for tributary discharge, suggesting other measures. (in Portuguese). Available at: ttp://www.cetesb.sp.gov.br/Agua/praias/res_conama_357_05.pdf.

[24] BRAGA, B., PORTO, M., TUCCI, C.E.M. (2006). Monitoring of water quantity and quality (in Portuguese). In: Rebouças, A.C., Braga, B., Tundisi, J.G. (Eds.), **Sweet Waters in the world and in Brazil** (in Portuguese). Escrituras, São Paulo, pp. 145-160.