Impacts on the springs of Cintra Stream (Botucatu, São Paulo State, Brazil) and downstream variations in water quality

Estudo dos impactos provocados sobre as nascentes do Córrego do Cintra (Botucatu, SP) e variações na qualidade de água ao longo de seu percurso

Belluta, I.[1], Silva, AMM. da[1], Camargo, CHC.[2] and Rall, VLM.[2]

[1]Departamento de Química e Bioquímica, Instituto de Biociências – IB, Universidade Estadual Paulista – UNESP, Distrito de Rubião Jr., s/nº, CEP 18618-000, Botucatu, SP, Brazil
e-mail: ibelluta@bol.com.br, ammsilva@ibb.unesp.br

[2]Departamento de Microbiologia e Imunologia, Instituto de Biociências – IB, Universidade Estadual Paulista – UNESP, Distrito de Rubião Jr., s/nº, CEP 18618-000, Botucatu, SP,
Brazil e-mail: btcarlos@gmail.com, vlmores@ibb.unesp.br

Abstract: Aim: The aim of this work was to assess water quality at Cintra Stream (Botucatu, São Paulo State, Brazil) springs and, to suggest restoration measures. **Methods:** Physicochemical and microbiological parameters were bimonthly sampled for one year (June/05 to May/06) at eight sites over the stream. **Results:** Electrical conductivity annual mean was 175.6 μS.cm^{-1} at S_2 (WTP-SABESP stabilization lagoons); besides, CO (5.9 mg.L^{-1}) and BOD_5 (4.4 mg.L^{-1}) gradually decreased downstream. This improvement was also verified through dissolved oxygen (DO) depletion, since at springs of Cintra stream DO mean level was initially low (4.4 mg.L^{-1}) and gradually increased until S_8 (Enviromental Protection Área - EPA; 8.6 mg.L^{-1}), but consumed oxygen values increased between these sites, which demonstrate self-depuration capability of the stream. All parameters were lower at the spring than at the stabilization lagoons located along the course, but the former receives non-treated sewage. There was localized contamination by thermotolerant coliforms (2,400 NMP.mL^{-1}), above the maximum limit allowed by the National Council for the Environment– CONAMA, Class III for animal consumption (1,000 NMP.mL^{-1}) and secondary-contact recreational use (until 2,500 NMP.mL^{-1}). **Conclusion:** Programs encouraging farmers on spring recovery, besides riparian forest restoration, and actions against effluent discharge will help improve headwater quality as well as its use.

Keywords: thermotolerant coliforms, sources, physicochemical parameter, water quality, Cintra Stream.

Resumo: Objetivo: Analisar a qualidade e propor medidas de recuperação da qualidade de água na nascente do Córrego Cintra (Botucatu, Estado de São Paulo, Brasil). **Métodos:** Foram analisados parâmetros físico-químicos e microbiológicos amostrados bimestralmente durante um ano (junho/05 a maio/06) em oito locais distribuídos ao longo do córrego. Os dados são discutidos em termos de médias anuais, desvio padrão e comparação entre médias (teste de Tukey). **Resultados:** Entre os parâmetros analisados, a condutividade elétrica apresentou média anual 175,6 μS.cm^{-1} no P_2 (lagoas de estabilização ETE-SABESP); o OC (carbono orgânico; 5,9 mg.L^{-1}) e a DBO_5 (4,4 mg.L^{-1}) mostraram diminuição gradativa ao longo do córrego. Esta melhora também foi verificada pela depleção do oxigênio dissolvido (OD), pois na nascente inicia-se com baixo teor médio de OD (4,4 mg.L^{-1}) e se eleva gradativamente até o P_8 (Área de Preservação Ambiental - APA; 8,6 mg.L^{-1}). O inverso ocorre com os valores de oxigênio consumido entre esses locais demonstrando a sua capacidade de autodepuração. Observou-se também, focos pontuais de contaminação por coliformes termotolerantes com 2400 NMP.mL^{-1}, cujo acima do limite máximo permitido pelo Conselho Nacional do Meio Ambiente – CONAMA, Classe III, para a dessedentação de animais é de 1000 (NMP.mL^{-1}) e para uso de recreação de contato secundário não deverá exceder 2500 NMP.mL^{-1}. **Conclusões:** Através de Programas de incentivo ao pequeno agricultor na recuperação da nascente, reflorestamento da mata ciliar e ações com a finalidade de extinguir focos existentes de lançamento de efluentes, poderão implicar na melhor qualidade da água na nascente bem como para o seu uso.

Palavras-chave: coliformes termotolerantes, nascentes, parâmetro físico-químico, qualidade de água, Córrego do Cintra.

1. Introduction

Spring of a river or stream is defined as a natural hole on the ground, from where subterranean water flows. A small stream will be formed that will successively contribute to the volume of another course of water until reaching the sea (Castro, 1999). Springs, "the water factories", must be preserved and rationally used, as a principle of sustainability (Rodrigues, 2006).

According to the water flow, river springs are classified into perennial (continuous flow), temporary (flowing only in the rainy season), and ephemeral (appearing during rain, remaining for some days or hours). Based on the reservoir type to which springs are associated, they are called slope or localized sources and diffuse ones (Castro and Gomes, 2001). Thus, they provide perennity or not to the micro-watershed. The ideal spring, providing high-quality, abundant and continuous water, is located next to the usage site, and has elevated topographic quota, making its distribution determined by gravity, without energy waste (Calheiros et al., 2004).

The micro-watershed, in a preserved natural ecosystem, is the basis for the regular production of water and, for environmental services (Rodrigues, 2006). Natural vegetation is constituted of the riparian forest occurring along water courses, in places subjected to temporary flood and sources. The micro-watershed plays an important role in the maintenance of water quantity and quality, soil stability and erosive process control (Passos, 1998).

In watershed management, resources preservation , as well as the interfering factors in a landscape geomorphologic unit must be regarded as the most suitable form of systemic manipulation of resources in a region (Calheiros et al., 2004).

Soares et al. (2006), aiming to restore riparian and source forests in parts of Guaratinguetá stream, São Paulo State, introduced a heterogeneous reforestation using native species. Studies on nature phenomena were associated with the dynamics of land occupation by humans (Carvalho, 2006). Ferreira et al. (2007) evaluated the natural regeneration process of the vegetation surrounding a river source in Lavras, Minas Gerais State, Brazil, in order to contribute to restoration and conservation.

Forest conservation in all biomes, Permanent Preservation Areas (PPA; springs and riparian forests) and Legal Reservation Areas (LRA; forests) contributes to maintain conservation of water and biodiversity. This is fundamental to preserve life on Earth, as well as to assure humans an in situ germplasm bank as a living source of plant essences and wild animals (Rodrigues and Carvalho, 2006).

Present work aimed to analyze water quality of a spring, to assess the anthropogenic effects in Cintra Stream and relationships with soil occupation, pollution sources and water use, and to suggest measures for rural management, conservation and recovery of the source and riparian forests.

2. Material and Methods

Botucatu County is located in the central south region of São Paulo State, 230 km away from the capital. The landforms in this region favor the formation of waterfalls; the relief, called "Cuesta of Botucatu", is a water divisor for the watersheds of Paranapanema and Tietê Rivers, and is located at 950 m altitude (Souza et al., 2003).

Cintra Stream, an affluent of Tietê Watershed, starts in the Botanical Garden, inside the campus of São Paulo State University (UNESP), Rubião Junior District, Botucatu. From the springs to approximately 5 km downstream is Pavuna Ecological Park, which has several waterfalls. Between the source and the waterfalls, the streambed is influenced by pastures, orchards, grain and vegetable cultivations, animal consumption areas, and no riparian forest is found

Diffuse non-pontual sources are identified in the stream, because they occur in lowland or marsh areas. Cintra Stream springs are classified as perennial. According to Embrapa classification (1999), relief topography is < to 8% and is therefore considered moderately wavy. Appropriate land use and soil conservational practices in these areas are extremely important to allow rain water interception, superficial flow velocity and quantity decrease, and infiltration increase, making possible the water-table recharge, for feeding the springs (Pinto et al., 2004).

To evaluate the conservation degree of the Cintra Stream source area, according to the protocol of Callisto et al. (2002), sampling site 1 ($S_{1,}$ the spring area), downstream (300 m)of a lake, was classified as impacted environment due to the presence of landfill and absence of riparian forest.

Using informations in Horton (1945) and, Villela and Mattos (1975), the following physiographic data were obtained for the Cintra stream micro-watershed: form factor (Kf) = 0.39; compacity coefficient (Kc) = 1.23; circularity index (Ic) = 0.65; drainage density (Dd) = 1.104 $km.km^{-2}$; and water-course sinuosity (Sin) = 1.144. These data indicate that the stream is not prone to overflow, and the 13% mean declivity (Dm) from springs to the mouth zone (S_1 to S_6) suggests that the micro-watershed is in the range above 12%, a wavy watershed (Embrapa, 1999). Simple calculation, besides the program AutoCAD Map 2000, including charts of Brazil, as well as map design through scanner digitalization and digital planimetry system (Silva et al., 1993) were used to estimate the features such as drainage net, plant distribution, crops, pastures, and arable areas of the micro-watershed area (Table 1).

Water was sampled bimonthly during a year (from June 2005 to May 2006) at eight different sites along Cintra Stream, six (S_1 to S_6) are inside the micro-watershed and

Table 1. Description of the soil occupation and measures of the occupied areas in Cintra Stream Micro-watershed, Botucatu, São Paulo State, Brazil.

Soil occupation	Occupied area (Ha)	(%)
Pasture	586.1383	54.45
Rubião Junior District	41.4989	3.86
Vista Alegre Land Parcel	94.3068	8.76
Eucalyptus	39.021	3.62
Capão Bonito Rural Land Parcel	17.6216	1.64
Forest	155.6534	14.46
Crops	142.24	13.21

two (S_7 and S_8) are downstream to the mouth (Figure 1). Water sampling was done at a minimum of 5-day drought interval to avoid compromising of the environment natural condition due to rain water dilution.

Water physicochemical parameters were determined according to Golterman et al. (1991) and the Standard Methods for the Examination of Water and Wastewater (Greenberg et al., 2005). Water and air temperatures, as well as pH, were measured with a digital field thermometer linked to a pH meter (Hanna Instruments, HI 221 model). Electrical conductivity (EC) was assessed with a conductivi-

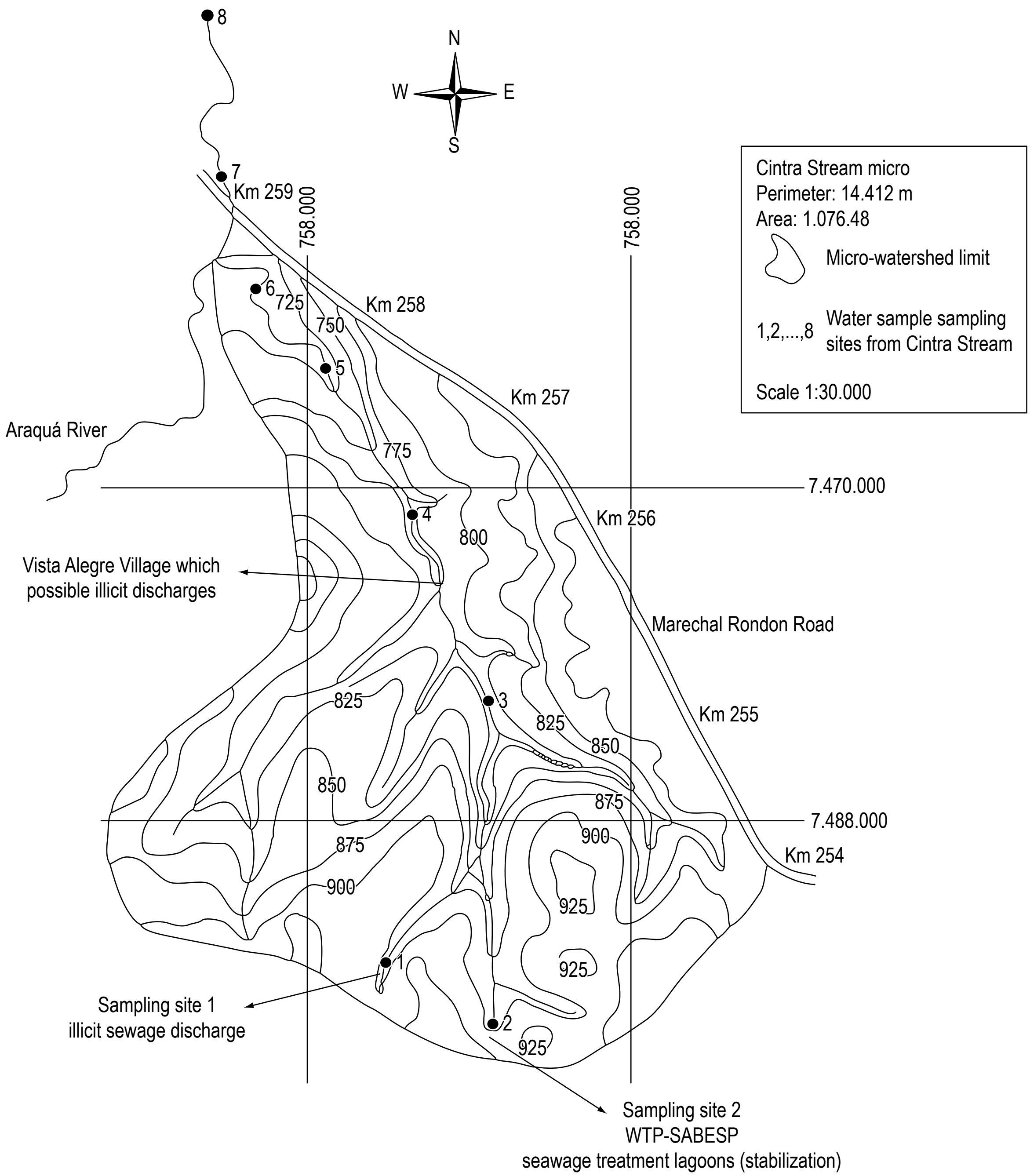

Figure 1. Cintra Stream Micro-watershed.

meter (Hanna Instruments, HI 2300 model), and turbidity with a turbidimeter (Turbiquat, 1500T model). Dissolved oxygen (DO) and biochemical oxygen demand (BOD_5) were measured according to the modified method of Winkler (Cetesb, 1989; Golterman et al.,1991; Greenberg et al., 2005). The permanganate method was employed to determine the consumed oxygen (CO) (Adad Tajra, 1982: Greenberg et al., 2005). For microbiological parameters, the multiple-tube method was adopted to assess total and thermotolerant coliforms (Greenberg et al., 2005).

Callisto et al. (2002) presented an evaluation protocol for a group of parameters in categories graded according to the observation of the habitat conditions. In the present study, the adopted protocol was composed of two tables: the first evaluates watershed characteristics and the environmental impact level due to anthropic activity; the second considers the habitat features and the conservation level of the natural conditions. The final grades reveal the preservation level of the ecological condition in sites of the watershed, in which 0-40 points represent "impacted" area; 41-60, "altered" area; and >61 points, "natural" area.

To verify the behavior of each variable at the sampling sites, analyses of variances followed by Tukey's test (Tukey's Studentized Range – HSD) were carried out, at 5% significance level (Zar, 1999).

3. Results

The most significant spatial variation was detected at S_1 and S_2, in which there was discharge of sewage and treated effluent from WTP-SABESP stabilization lagoons, since pH was close to neutrality. From S_3 to S_8, mean pH values did not statistically vary, although with a trend to alkalinity (Table 2). There was no influence of pluviosity even in those months presenting higher rainfall (Figure 2), since a 5-day drought period was respected before samplings in order to do not damage the natural environmental condition due to rainfall dilution.

Water and air temperatures did not statistically differ over the year (Table 2) at each site and month. The minimum and maximum annual air temperature means in the studied period were 19.6 and 22.5 °C, respectively. For water temperature, the minimum annual mean was 19 °C and the maximum, 21.4 °C.

Turbidity was only statistically different at S_1 (18.5 NTU) in all six samplings periods. At the remaining sites, it ranged from 4.6 to 10.8 NTU (Table 2).

The EC variation range in all six months indicates a significant difference at S_2 (175.6 $\mu S.cm^{-1}$) and a gradual decrease in mean values from S_3 to S_8 (Table 2). EC value at S_1 was significantly higher in November/2005 (Figure 3a). Values were also high from S_2 to S_4 (Figures 3b, d) in most of the samplings, as well as at the other sites (Figures 3e, h), except for September/2005 (Figure 3e), in which values were lower than 100 $\mu S.cm^{-1}$, indicating less impacted environments (Cetesb, 2007a).

The annual mean of total and thermotolerant coliforms did not statistically differ at all sites and months (Table 3).

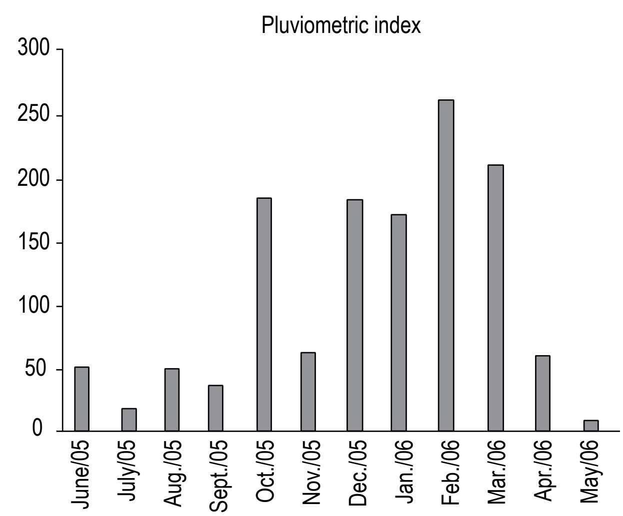

Figure 2. Pluviometric index (mm). Data supplied by the Department of Natural Resources/Environmental Sciences, Agronomical Sciences College – FCA, São Paulo State University – UNESP, Botucatu, São Paulo State, Brazil.

Table 2. Results of Tukey's test and comparison of the variables pH, air and water temperatures, turbidity, and electrical conductivity in Cintra Stream, Botucatu, São Paulo State, Brazil.

Sites	pH	Air temperatures (°C)	Water temperatures (°C)	Turbidity (NTU)	Electrical conductivity ($\mu S.cm^{-1}$)
S_1	7.1 ± 0.7^{B}	22.5 ± 3.4^{A}	19.4 ± 2.2^{A}	18.5 ± 7.4^{A}	78.2 ± 40.4^{C}
S_2	6.9 ± 0.4^{B}	20.2 ± 2.7^{A}	21.4 ± 1.8^{A}	10.8 ± 5.0^{B}	175.6 ± 37.2^{A}
S_3	7.8 ± 0.6^{AB}	20.4 ± 2.9^{A}	19.0 ± 2.4^{A}	4.6 ± 1.8^{B}	121.4 ± 10.5^{B}
S_4	7.8 ± 0.6^{AB}	22.2 ± 3.2^{A}	20.0 ± 2.3^{A}	5.9 ± 2.8^{B}	101.9 ± 14.8^{BC}
S_5	7.7 ± 0.6^{AB}	22.2 ± 2.9^{A}	19.8 ± 2.2^{A}	6.5 ± 2.5^{B}	94.1 ± 10.8^{BC}
S_6	7.7 ± 0.6^{AB}	21.2 ± 2.8^{A}	19.8 ± 2.5^{A}	6.9 ± 2.7^{B}	86.4 ± 4.8^{BC}
S_7	7.8 ± 0.6^{AB}	19.6 ± 2.9^{A}	19.9 ± 2.4^{A}	7.6 ± 2.7^{B}	80.6 ± 2.8^{C}
S_8	8.2 ± 0.5^{A}	18.4 ± 3.6^{A}	19.2 ± 2.1^{A}	6.8 ± 2.1^{B}	77.9 ± 3.2^{C}
Value of "p"	0.021	0.27	0.74	<0.001	<0.001

Means followed by the same letter do not statistically differ at 5% significance level.

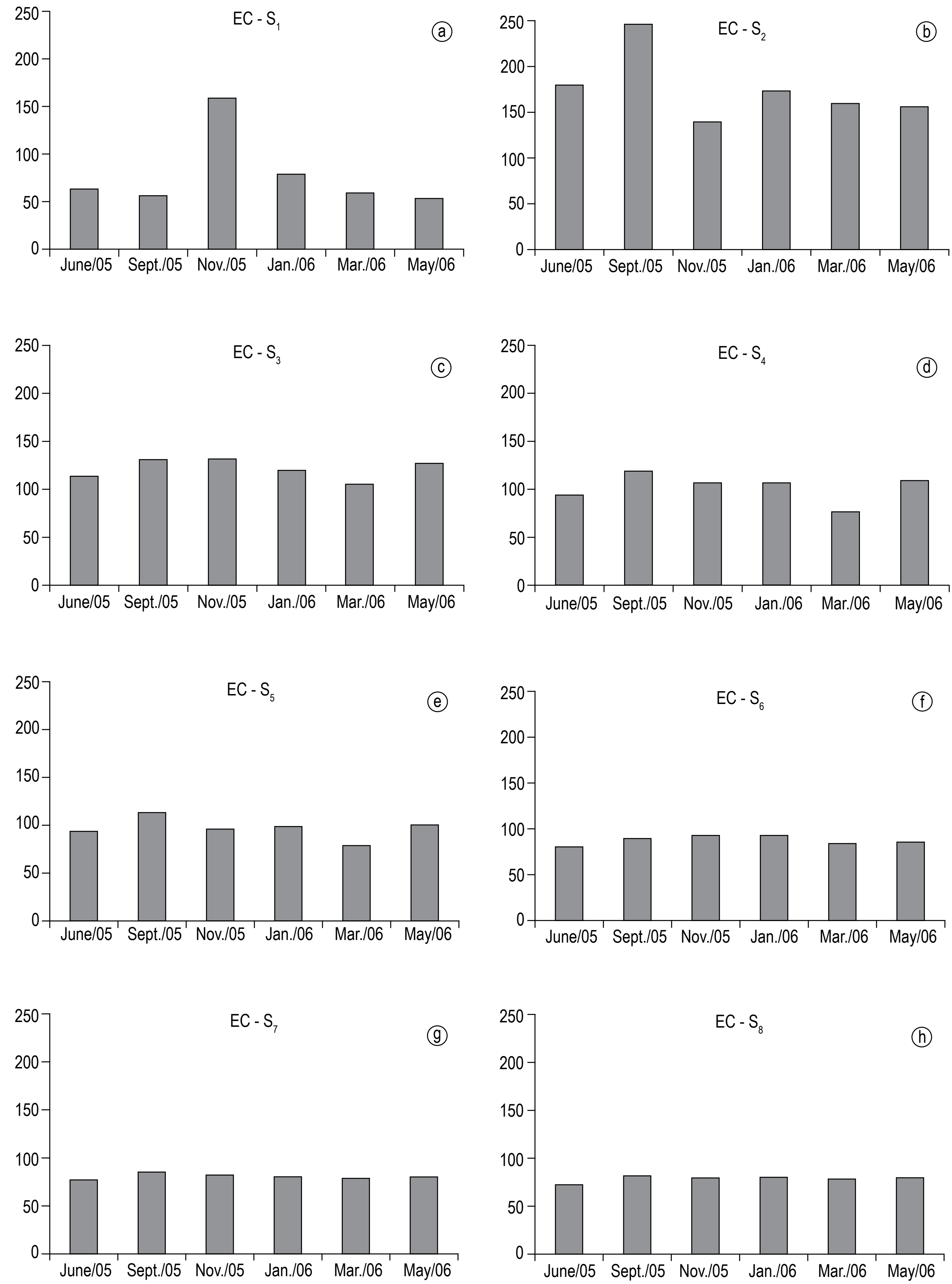

Figure 3. Electrical conductivity (µS.cm^{-1}) measures at each site and collection from the source to the mouth of Cintra Stream, Botucatu, São Paulo State, Brazil.

Thus, significant numbers of thermotolerant coliforms were obtained in January/06 at S_3 and S_4; the same values were recorded in May/06 at S_2, S_4 and S_5 (Table 4). At the remaining sites, values were inferior to 460 $MPN.mL^{-1}$. In January/2006 and May/2006, the number of total coliforms was also significant at S_4 and S_5 (1100 $MPN.mL^{-1}$); the remaining sites had values lower than 240 $MPN.mL^{-1}$.

The annual DO means significantly differed at S_1 and S_2, which presented depletion (4.40 and 4.90 $mg.L^{-1}$, respectively; Table 3). DO range was below 6 $mg.L^{-1}$ at all sites and samplings, except for September/05 (Figures 4a), when DO level was 7.47 $mg.L^{-1}$, indicating good oxygenation in the stream because no effluent was discharged during this period. At S_3 (Figure 4c), DO concentration was lower than 6 $mg.L^{-1}$ only in September/05. At the remaining sites and collections (Figures 4d, h), values were high.

Increasing DO levels were observed from S_1 to S_8 (Figures 4a, h) and, at contamination sites (S_1 and S_2), there was gradual oxygenation increase. On the other hand, CO level means were inversely proportional to those of DO (Figure 5).

Oxygen consumption at S_1 was not higher than 3.6 $mg.L^{-1}$ (Figure 6a). At S_2, CO level was high and indicated higher or lower organic load to be oxidized, according to the sampling dates (Figure 6b). A gradual decrease in CO mean values in all months is shown in Table 3. Besides, Figures 6c to H indicate a decrease in oxygen consumption at most sites until S_8. In addition, CO mean values decreased whereas DO mean values increased (Figure 5).

For DBO_5 assessment, S_2, S_4 and S_8 were strategically chosen due to the influence area, which discarded the need of analyzing the remaining sites considering the reduced organic load. S_2 was chosen due to the presence of WTP-SABESP treated effluent; S_4, due to its proximity to Vista Alegre Village considering possible illicit discharges; and S_8, due to the presence of upstream agropasture areas.

Similarly to CO, BOD_5 concentration was high at S_2 and gradually decreased from S_4 to S_8 due to the lower organic load (Figure 7).

The final score proposed by Callisto et al. (2002) to evaluate the conservation degree of the surrounding areas of each site was as follows: S_1 = 30 points; S_2 = 20 points;

Table 3. Results of the Tukey's test and comparison of the water microbiological and physicochemical variables in Cintra Stream, Botucatu, São Paulo State, Brazil.

Sites	Total coliforms	Thermotolerant coliforms	Dissolved oxygen	Consumed oxygen	Biochemical oxygen demand
S_1	167 ± 102^A	284 ± 98^A	4.4 ± 2.3^C	2.2 ± 1.3^B	-
S_2	190 ± 94^A	673 ± 978^A	4.9 ± 1.1^{BC}	5.9 ± 2.0^A	4.4 ± 0.9^A
S_3	607 ± 1005^A	637 ± 989^A	7.2 ± 1.3^A	2.3 ± 0.4^B	-
S_4	368 ± 419^A	1104 ± 1183^A	7.4 ± 0.4^A	1.3 ± 0.4^B	1.3 ± 0.5^B
S_5	282 ± 466^A	629 ± 1006^A	6.9 ± 0.6^{AB}	1.2 ± 0.4^B	-
S_6	153 ± 118^A	113 ± 115^A	7.4 ± 0.8^A	1.0 ± 0.5^B	-
S_7	210 ± 66^A	284 ± 98^A	7.9 ± 0.9^A	1.0 ± 0.4^B	-
S_8	197 ± 97^A	240 ± 154^A	8.6 ± 0.6^A	0.7 ± 0.5^B	0.6 ± 0.4^B
Value of "p"	0.72	0.48	<0.001	<0.001	<0.001

Means followed by the same letter do not statistically differ at 5% significance level.

Table 4. Number of total and thermotolerant coliforms from the source to the mouth of Cintra Stream, Botucatu, São Paulo State, Brazil.

		S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
	June/05	>3	>3	>3	>3	>3	>3	>3	>3
Thermotolerant	September/05	240	23	240	240	23	23	240	240
coliforms	November/05	240	240	240	240	240	240	240	240
($MPN.mL^{-1}$)	January/06	460	460	2400	2400	460	43	460	460
	March/06	240	240	64	240	23	23	240	23
	May/06	240	2400	240	2400	2400	240	240	240
	June/05	>3	>3	>3	>3	>3	>3	>3	>3
	September/05	240	240	240	240	240	240	240	240
Total	November/05	240	23	240	240	23	23	240	240
coliforms	January/06	23	240	2400	23	23	240	240	240
($MPN.mL^{-1}$)	March/06	93	240	64	240	23	23	93	23
	May/06	240	210	93	1100	1100	240	240	240

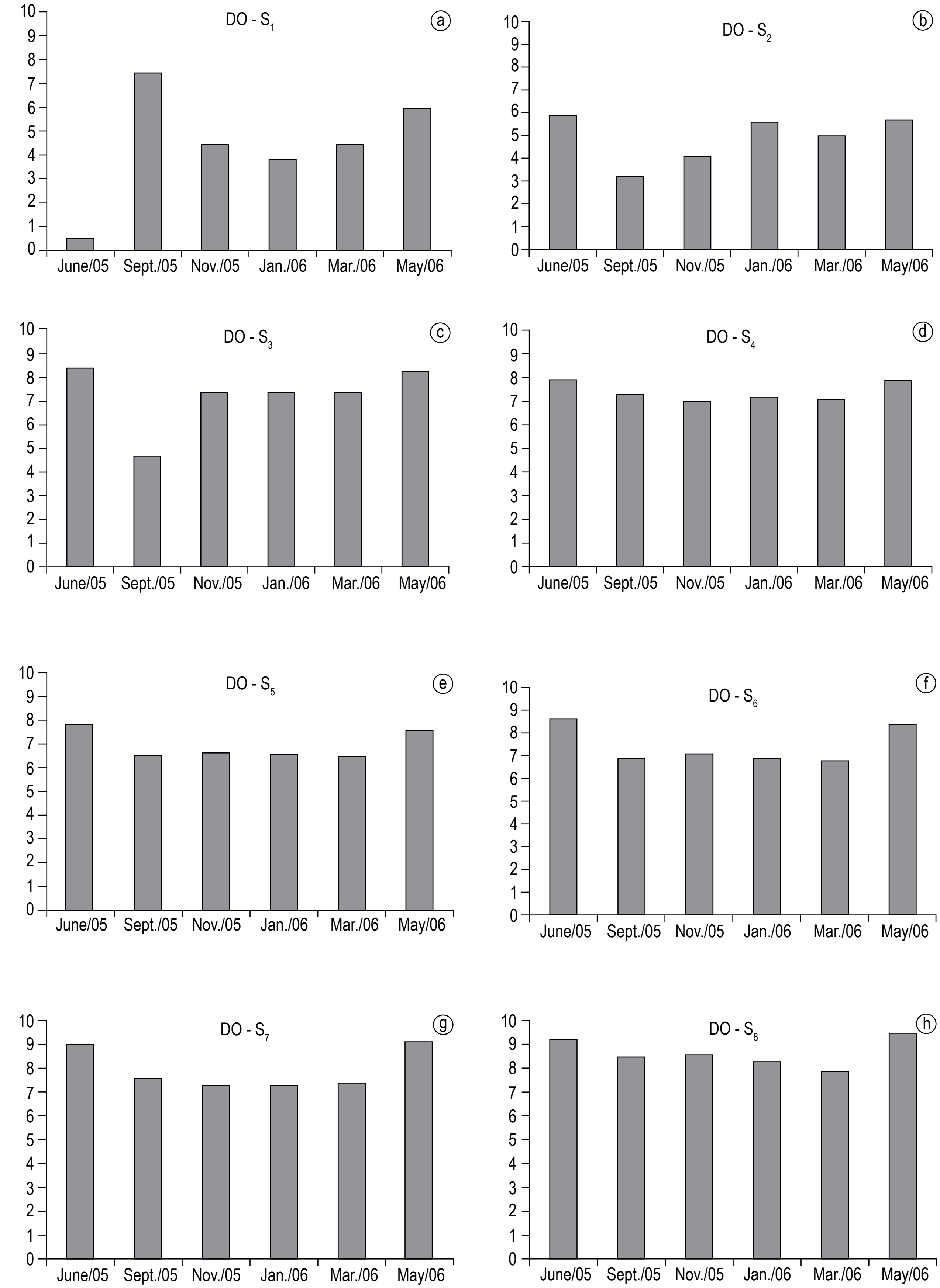

Figure 4. Dissolved oxygen level (mg.L^{-1}) at each site and collection from the source to the mouth of Cintra Stream, Botucatu, São Paulo State, Brazil.

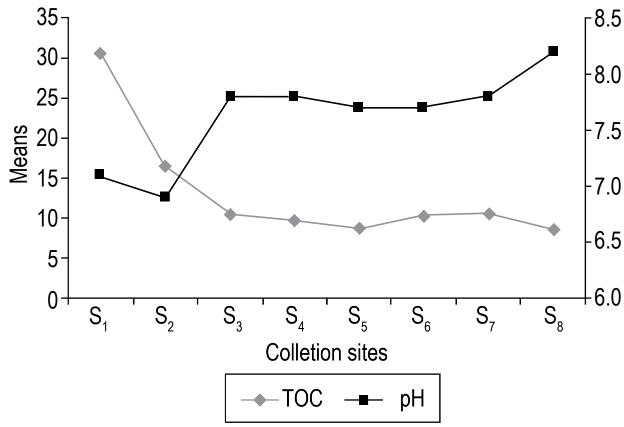

Figure 5. Annual means of dissolved (DO) and consumed (CO) oxygen levels (mg.L^{-1}) in Cintra Stream, Botucatu, São Paulo State, Brazil.

S_3 = 68 points; S_4 = 40 points; S_5 = 50 points; S_6 = 51 points; S_7 = 68 points and S_8 = 88 points.

4. Discussion

To ensure water access, a quality criterion must be established according to the usage purpose. Water body classification according to the aimed quality is one of the most important tools for watershed management. River water in the national territory is classified based on the quality required for its usage. Higher-quality water can be employed for less demanding usages, as long as its quality is not affected (Conama, 2005). Cintra Stream water is destined for tree crop irrigation, secondary-contact recreation (sporadic or accidental use with small possibility of ingestion), and animal consumption. For such purposes, Conama (2005) established Class III, which was used as a parameter for all variables of the present study.

The utilization of several parameters to quantitatively determine the impact of anthropogenic pollution on aquatic communities has been common. Tools capable of measuring the water quality are useful for the detection of pollutant loads in the water composition. Parameters like pH, water temperature and electrical conductivity are frequently employed (Ranalli, 1998).

In the present study, pH was neutral next to the source of Cintra Stream (S_1) and downstream of WTP-SABESP sewage treatment lagoons (S_2). At the spring, there is probable untreated illicit sewage discharge directly into the stream, which sensitively alters the analyzed parameters. At S_2, there are innumerous organic and inorganic compounds degraded and dissolved in residuary waters.

The treated effluent is not subjected to rainfall and consequent dilution since it is located at treatment lagoons but discharged into Cintra Stream at 420 m, upstream from S_3, under dilution effect only of waters from the source (S_1), located at 490 m.

Marques et al. (2007) studied the impact on crop areas and obtained low pH values in rainy periods, demonstrating thus the effect of agrochemical leaching on the Ribeira River Watershed, São Paulo State, Brazil. Rainfall leads to a probable dilution of the organic acids released by overflowed soils into the stream (Carvalho et al., 2000; Moretto and Nogueira, 2003). Also, Marques et al. (2007) only detected agrochemical residues when rainfall was above 300 mm. Here, this index was lower than 262.7 mm rain and the 5-day drought period was respected.

At S_8, pH increase can be due to the sampling station localization at "Cuesta Basáltica" (EPA), where the stream flows over basalt slabs. According to Araujo et al. (2002), the original soil in Botucatu County is the methaphyre likely diabasic (basaltic eruptives), but Leinz and Amaral (1980) stated that the terms acid, basic or neutral regarding rocks are not related to their respective chemical properties. Press et al. (2006) mentioned that rocks undergo a very slow chemical weathering or a chemical alteration followed by physical weathering, in which the particles originated due to the mechanic breakdown chemically change the environment. In basaltic rocks, for example, silicates are meteorized through hydrolysis under water presence and become more acid.

Thus, the alkalinity obtained from S_3 is probably not related to the basalt but to the influence regarding soil type and use in the region. The high pH at S_8, located on the waterfall bottom presenting water dam (lentic environment), is probably due to the accumulation of alkaline species originated from agricultural areas (S_3 and S_7) and carried out over the stream.

The annual pH mean in the present study is within the acceptable range reported by Conama (2005) for water bodies (between 6 and 9). Studies have also shown that most of the living organisms better adapt to a pH value close to neutral (Nuvolari et al., 2003).

Temperature variations are part of the normal climate scheme, and natural water bodies present seasonal and daytime variations (Cetesb, 2007a). In the edges of rivers surrounded by forest, there is a tendency towards lower air and water temperature due to shadow, which reduces the incident radiation (Carvalho et al., 2000). At S_1 and S_2, there are areas without riparian forests and therefore directly influenced by sun rays. Both facts respond to slight alterations in the air and water temperatures but did not statistically vary over the seasons in Cintra Stream.

Water turbidity is normally elevated in the rainy season and reduced during the dry season due to the increase in suspended particles (Panhota and Bianchine, 2003). Moragas (2005) reported that the ratio between turbidity and coliforms constituted the most important problem at the water collection site for treatment and public supply in Jataí, Goiás State, Brazil, since turbidity is more frequent during rainy periods and high in crop areas due to soil

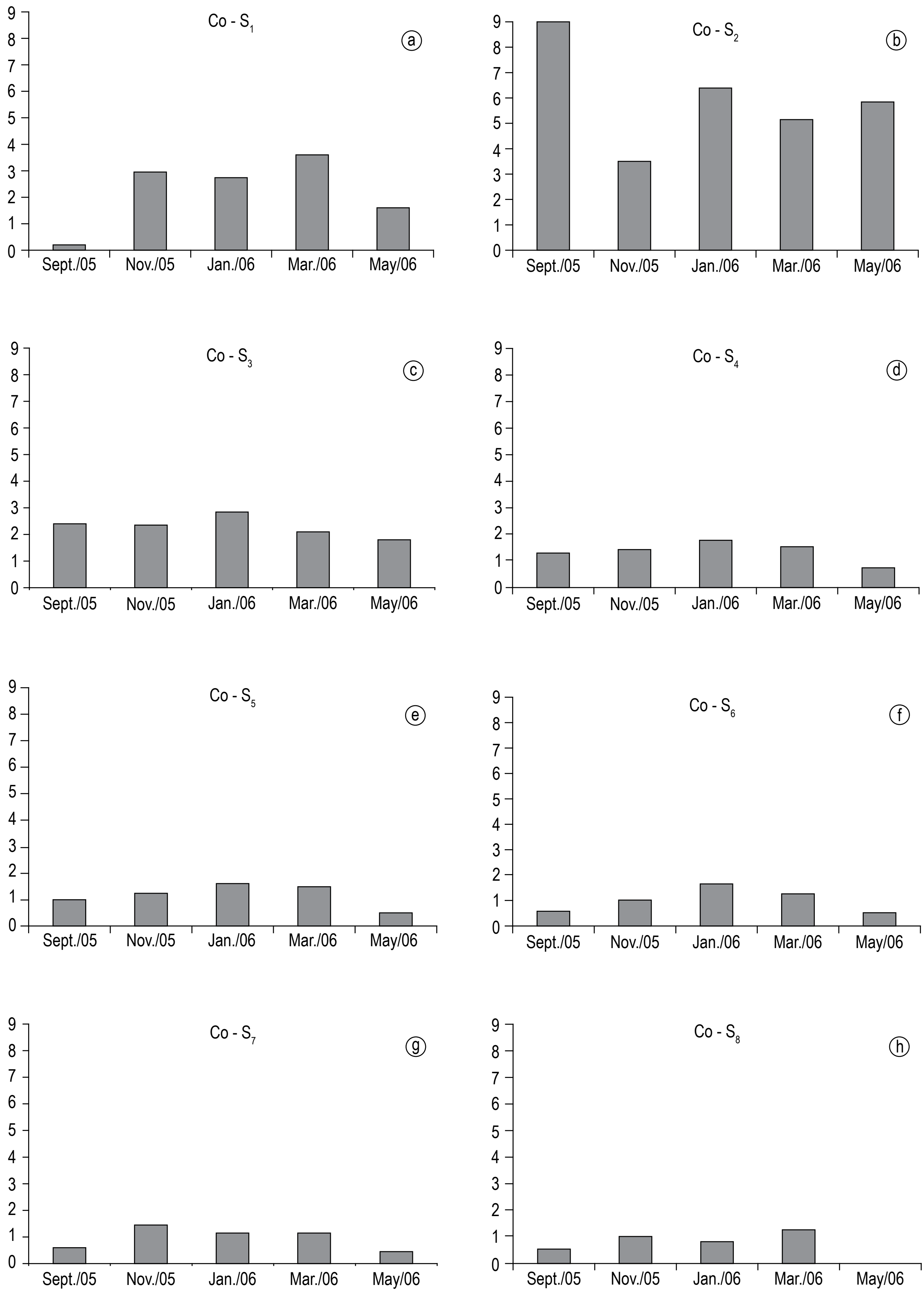

Figure 6. Consumed oxygen (CO) levels (mg.L^{-1}) at each site and collection from the source to the mouth of Cintra Stream, Botucatu, São Paulo State, Brazil.

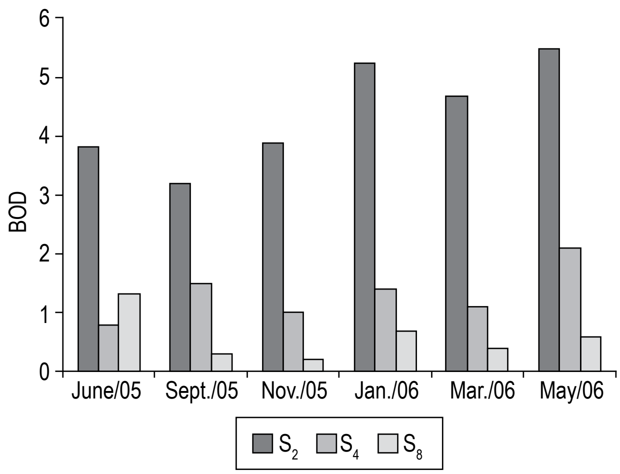

Figure 7. Biochemical oxygen demand ($mg.L^{-1}$) at each site and collection from the source to the mouth of Cintra Stream, Botucatu, São Paulo State, Brazil.

adsorption of agrochemicals which, when transported by superficial drainage, introduce toxic loads aggregated to the soil particles. In the present study, turbidity had no significant alterations, since annual means were inferior to 100 NTU, which is considered the maximum allowed limit (Conama, 2005). The presence of coliforms was not due to the rainy season but to the effluent discharge (S_1 and S_2) and proximity to residential and animal confinement areas (S_3, S_4 and S_5).

EC can be related to pluviometric index because salt concentration in the water body increases in periods of scarce rain and is diluted in periods of heavy rain (Cetesb, 2007b). Psilovikos et al. (2006) verified that low EC values frequently coincide with high water levels in Nestos River (Bulgaria), which justifies dilution. Souza (2005) studied the quality of the effluent treated in WTP-SABESP sewage treatment lagoons, upstream of S_2 in the present study, and found no significant interference related to rain and dry periods. From S_2 (WTP-SABESP), EC tended to gradually decrease due to the waters received from upstream tributaries; only from S_2 to S_4, values were higher than 100 $\mu S.cm^{-1}$, which indicates impacted environment (Cetesb, 2007a).

Considering the analyzed parameters, only EC levels were higher than those specified by Conama (2005). This was due to the WTP-SABESP sewage treatment plant (S_2). In general, EC was apparently similar among S_1, S_7, and S_8, and among S_4, S_5, and S_6. Also, significant variation was observed at S_2 and S_3. S_3 receives organic load from both S_1 and S_2 besides an upstream tributary, which determines the organic load dilution effect and consequent decrease in EC values. For the remaining parameters, values were relevant.

Coliform bacteria are present in both natural and sewage-contaminated waters, which have differences only regarding the bacteria origin (Silva et al., 1998). Contamination due to sewage or the presence of animals constitutes an important economic and public health problem, since many pathogens can be transmitted to man (Brasil, 2004). In spite of the illicit sewage discharge, the number of thermotolerant coliforms at S_1 was smaller than 460 $MPN.mL^{-1}$ in all samplings; however, at S_2, S_3, S_4 and S_5, in several collections, this number was close to the maximum limit allowed for recreation (2,500 $MPN.mL^{-1}$), but higher than the limit of 1,000 $MPN.mL^{-1}$for animal consumption (Conama, 2005). The number of total coliforms was relevant as there are high quantities and varieties of these bacteria in nature.

As regards the punctual contamination sites in the studied period, S_2 (WTP - SABESP), S_4 (downstream of Vista Alegre Village) and S_5 (Agropasture) presented thermotolerant coliforms due to human and animal interference. Many studies about rivers in Botucatu and other regions of São Paulo State have identified severe contamination by thermotolerant coliforms. Correa et al. (2006) analyzed the water quality at the margins of Tietê River and found relevant numbers of thermotolerant coliforms, which are considered normal for recreation. Silva et al. (1998) detected large numbers of thermotolerant coliforms in waters for irrigation and animal consumption from spring to mouth of Botucatu rivers, which was due to the presence of humans and their agropasture activities, besides the presence of condominiums and use of septic tanks. Conte et al. (1999) detected thermotolerant coliforms around waterfalls due to pasture areas and cattle presence. Valente et al. (1999) carried out a bacteriological evaluation of the hydric resources in Eldorado County, Ribeira Valley, São Paulo State, where the peripheral population uses water from rivers and artesian wells. They observed a higher frequency of contamination by thermotolerant coliforms due to the absence of sanitation and hygiene personal habits, since fecal matter is directly eliminated into these types of hydric resources.

The above-mentioned studies about thermotolerant coliform contamination in water bodies reflect the situation of the rivers surrounding Brazilian cities. Cintra Stream is another example and, when the coliform contamination data are associated with the physicochemical parameters analyzed so far, we can assess future public health risks to riparian populations, pets and recreational users.

DO is one of the best parameters that demonstrates aquatic ecosystem restoration and organic matter degradation, but should not be the only considered factor, since its concentration can be affected by several other factors and not only by the anthropic action.

Strieder et al. (2006) showed that the distribution patterns of benthic macroinvertebrates in a watershed reflected the environmental characteristics and the water quality in the different segments of Peão Creek and Sinos River, Rio Grande do Sul State, Brazil. Schneck et al. (2007) observed a steep water quality gradient in a stream with high levels of total nutrients and solids, and consequent change of epilitic diatom communities including species characteristic of oligotrophic environments for species indicator of eutrophic environments. These factors were analyzed by several authors and indicate the natural condition of water quality in the biota inside and surrounding the water body. DO is a biota-inhibitor agent in the water (Nuvolari et al., 2003). According to Chapman and Kimstach (1992), DO concentrations inferior to 5 $mg.L^{-1}$ can affect the behavior and survival of aquatic communities, and levels inferior to 2 $mgO.L^{-1}$ may lead to the death of most fish. Based on Conama (2005), the maximum allowed limit for Class III streams should not be lower than 4 $mg.L^{-1}$.

In the present study, DO mean values significantly differed between S_1 and S_2, which were also different in relation to the remaining sites. DO level was lower at S_1 (June/05) and S_2 (September/05), relative to the remaining sites and sampling periods.

The mean levels of DO gradually increased with the distance from S_1 and S_2. DO content in the water body is directly proportional to the atmospheric pressure and inversely proportional to temperature (Baird, 2002; Nuvolari et al., 2003). According to Moretto and Nogueira (2003), the relationship between altitude and water oxygenation is related to the atmospheric pressure on the water column, which improves oxygenation. Oxygen introduction into the water is higher at the sea level, and the higher the altitude, the lower the oxygenation. On the other hand, dissolution is directly proportional to the water turbulence degree (Nuvolari et al., 2003). Janzen and Schulz (2006) carried out a laboratorial study on the interaction between the turbulence on the bottom and gas interference through air-water interface. They observed that high DO levels are captured on the water surface and taken to the fluid center, decreasing superficial DO according to the caused turbulence. In the present study, the different altitudes at the sampling sites resulted in water mean temperature range between 19.0 and 21.4 °C, which may lead to good water oxygenation in the stream. Since S_8 is located in Pavuna Ecological Park on the bottom of a waterfall, which causes intense turbulence and is at a lower altitude (616 m), relative to the spring (865 m), this site had high DO content.

At S_1, CO means were inferior to 0.5 $mg.L^{-1}$ in September/2005, which suggests good water quality, and superior to 1.5 $mg.L^{-1}$ in the remaining months, indicating higher DO demand due to the presence of organic matter. Similarly, values were higher than 3 $mg.L^{-1}$ at S_2, indicating water quality decrease. From S_3 to S_8, there was a gradual recovery of water quality due to the decrease in the organic matter content to be decomposed and consequent DO consumption. The annual means of DO and CO significantly express this behavior.

BOD_5 is the quantity of oxygen needed to oxidize the biodegradable organic matter, through aerobic microbial decomposition, to a stable inorganic form in a certain period (Cetesb, 2007a). According to Greenberg et al. (2005), BOD_5 indicates the quantity of oxygen consumed in 5-day incubation at 20 °C, and the organic matter in the water and effluents is composed of several compounds at several biological oxidation stages. At S_2, BOD_5 mean was notably elevated, and similarly to turbidity, EC and CO gradually decreased with the distance from the organic pollution sources. The lowest O_2 demand was observed at S_8 due to the higher water quality. Although BOD_5 was higher at S_2, relative to S_4 and S_8, at the former it did not exceed the maximum allowed limit equal to 10 $mg.L^{-1}$ (Conama, 2005).

DO, CO and BOD_5 levels again reflected the effect of the spring and the WTP - SABESP stabilization lagoons. There was an apparent similarity of DO and CO levels from S_3 to S_8, and a significant difference at S_2. BOD_5 and CO levels gradually decreased over the stream due to its declivity and the presence of tributaries, which favored the elevated DO content.

The influence of crops, pastures and areas without riparian forest were detected at S_4, S_5 and S_6. For Strahler (1957), this is a 3rd order stream, since the primary channel (S_1) is designated of 1st order and the junction of two primary channels (downstream to S_2) form another one of 2nd order, and the junction of two secondary channels (upstream to S_3) forms another one of 3rd order, which prevails until its mouth (downstream to S_6), which indicates that several tributaries contribute to its flow. According to Horton (1945) and, Villela and Mattos (1975), it is not prone to overflow. These physiographic characteristics, as well as the moderately wavy relief at S_1 and wavy relief from S_2 to S_6 (Embrapa, 1999), suggest excellent conditions for agroecological areas and water quality restoration from the source to the mouth of the stream. Araujo et al. (2002) studied 10 micro-watersheds from Capivara River in Botucatu and confirmed that the predominant relief class in the county is from slightly waving to waving.

Although the area of Jaguara Stream Watershed, Minas Gerais State, Brazil, is 5-fold higher than that of Cintra Watershed (56.42 km^2), of 6th order, its mean declivity is 12.37% (waving) and its morphometry also indicates low possibility of flooding; besides, of the 104 studied springs, 61.54% are degraded and 38.46% perturbed. The absence of native vegetation, erosions, silting, soil compactness by cattle, crops and "voçorocas" constituted the degradation factors in the sources (Brito Costa, 2004).

However, based on the protocol applied over Cintra Stream longitudinal gradient, according to Callisto et al. (2002), the analyzed areas corresponded to the same sampling sites; thus, S_1 and S_2 were considered impacted area; S_3, natural area; S_4, impacted area; S_5 and S_6, altered areas;

and S_7 and S_8 in the adjacent micro-watershed, natural areas (EPA). Pasture is predominant in the micro-watershed (S_1 to S_6), accounting for 54.45%, followed by PPA areas, 14.46%, and agricultural areas, 13.21%. At the remaining sites, there are land parcels, residential areas and eucalyptus cultivation. However, the classification of Callisto et al. (2002) reveals real impacts on the stream surrounding area, precisely identifying the sites that need riparian forest restoration, soil use and occupation through agroecological systems, elimination of illicit sewage discharge, and reestablishment of the source natural condition.

An example of management and recovery of watersheds and sources is observed in the county of San Pedro de Potrero Grande, Nicaragua, besides Honduras and El Salvador, where ranch owners receive financial support through a municipal accord named Payment for Environmental Services (PES) for sustainable agriculture and protection of water resources for supplying of local communities (Espinoza, 2006). In Brazil, according to the Coordination for Integral Technical Assistance – CATI (2008), the Micro-watershed Program aims to establish a preservation policy for soil and water, acting in the whole São Paulo State by encouraging rural communities to concern on actions, social and cultural values, and supporting activities that lead to positive results in environmental recovery and life quality of these communities through sustainability.

In the present study, the evaluations indicate a worrying anthropic action in the source (S_1), as well as treated effluent (S_2) effects over Cintra Stream, besides areas destitute of riparian forest. Since it is a PPA, the restoration and preservation of the source is essential within a minimum radius of 50 m, in order to protect it. In water courses with less than 10 m width, the source must be protected with a minimum width of 30 m (Conama, 2002). Preserving small affluents (<5 m) and recovering sources like Cintra Stream means to preserve the micro-watershed and large rivers that receive its waters, such as Tietê and Paraná Rivers.

5. Conclusions

The present results indicate "in natura" sewage discharge in the area of diffuse sources (S_1) in Cintra Stream Micro-watershed, which is forbidden by law. Differently from many others, this stream is severely compromised already from its headwaters. The sewage treatment lagoons (S_2) had significant values for almost all analyzed parameters. Besides these sampling sites, there are many areas of pasture, soil occupation and vulnerable riparian forest from S_4 to S_7. Microbiological parameters at S_2, S_3, S_4 and S_5, in several collections, were close to the maximum limit allowed for recreation but higher than the maximum limit allowed for animal consumption due to the presence of humans and animals in these areas. Based on the altered DO, CO, EC and BOD_5 levels in Cintra Stream and considering the physiographic characteristics of this micro-watershed, actions aimed at eliminating existent effluent discharge sites (S_1 and S_2) will help to improve water quality. Soil occupation from S_3 to S_7 through programs supporting small farmers, spring recovery, riparian forest restoration, as well as encouragement of organic management, are conservational practices that could contribute to the water quality improvement, allowing sustainable development in the rural area for all riparian population, including animal consumption, and recreation in waterfalls with no harm to the health of users.

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