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Physic-chemical evaluation of leach and water from the Borba Gato streamlet within the catchment area of the urban waste landfill of Maringá, Paraná State, Brazil

Marta Eliane Echeverria Borges* and Carlos de Barros Júnior

Departamento de Engenharia Química, Universidade Estadual de Maringá, Av. Colombo, 5790, 87020-900, Maringá, Paraná, Brazil.
**Author for correspondence. E-mail: borges_marta04@yahoo.com.br*

ABSTRACT. The physic-chemical characteristics of leach deposited in the landfill waste pond and of water from the Borba Gato streamlet are evaluated. Twenty-six physic-chemical parameters were analyzed from three collection sites, or rather, two in the streamlet, one upstream (P-01) and one downstream (P-02) of the landfill waste pond, and one in the leach deposit pond (P-03). The streamlet area under analysis was impacted due to being in an agricultural area and for its urban waste deposits. Parameter concentrations of aluminum, iron and mercury were reported above the quality standard of freshwater, according to Conama 357/2005 resolution (class 2). Further, throughout the rainy period, the ammoniac nitrogen content was above the resolution quality standard for fresh water. Moreover, landfill leach was above standards of effluent discharge established by Conama 357/2005. An efficient treatment for the effluent generated in Maringá is required since there is evidence of leach pollution of the Borba Gato streamlet.

Keywords: landfill leach, water quality, organic and inorganic materials.

Avaliação físico-química do lixiviado e da água do ribeirão Borba Gato na área de influência do aterro de resíduos de Maringá, Estado do Paraná, Brasil

RESUMO. Este estudo teve como objetivo avaliar as características físico-químicas do lixiviado depositado na lagoa do aterro e da água do ribeirão Borba Gato. Foram analisados 26 parâmetros físico-químicos de três pontos de coletas, dois no ribeirão, a montante (P-01) e a jusante (P-02) do aterro de resíduos, e um na lagoa de depósito de percolado do aterro (P-03). A área do ribeirão estudada se apresentou impactada, por ser uma região agrícola e pela deposição dos resíduos de Maringá. Dentre os parâmetros estudados, registrou-se que, na maioria dos meses, concentrações de alumínio, ferro e mercúrio estavam acima do padrão de qualidade de água doce da resolução do Conama 357/2005 (Classe 2). Além disso, verificou-se que no período chuvoso, P-02 registrou teores de nitrogênio amoniacal acima do padrão de qualidade de água doce da resolução, assim como o lixiviado do aterro apresentou-se acima do padrão do lançamento de efluentes estabelecido pelo Conama 357/2005. Deste modo, constata-se a necessidade de um tratamento eficaz para o efluente gerado no aterro de resíduos de Maringá, uma vez que há indícios de que o lixiviado tem poluído o ribeirão Borba Gato.

Palavras-chave: lixiviado do aterro, qualidade da água, materiais orgânico e inorgânico.

Introduction

The quality of water sources is highly influenced by the type of soil occupation and its use on the neighboring margins. Changes in the physical, chemical and biological characteristics of any natural environmental affect, directly or indirectly, its fauna and flora and, as a consequence, human beings.

The Borba Gato streamlet, approximate 8 km long, lies totally within the municipality of Maringá, Paraná State, Brazil. Its source lies in the Horto Florestal, a natural reserve within the urban area, and flows into the Pinguim streamlet (in the rural area) which, in its turn, discharges into the Ivaí river. The basin of the Borba Gato streamlet covers urban, rural, preservation, mineral exploration and urban waste landfill areas.

Current research studies the area of influence of the waste landfill of Maringá. In fact, one of the most serious problems in the final deposition of urban wastes occurs when waste decomposes and gases and leachate are released in the environment with several impacting issues such as water, soil and air pollution. Since the waste landfill lies some 70 m from the streamlet margins, current investigation evaluates the physical and chemical characteristics of the landfill leach deposited in the pond and in the water of the Borba Gato streamlet.

Material and Methods

Collections were undertaken monthly between March 2005 and March 2006. Three sampling sites were chosen: two in the Borba Gato streamlet, one upstream the urban waste landfill (P-01: at 23º29'02,128''S and 51º57'14,900''N), and the other downstream (P-02: at 23º28'25,796''S and 51º57'45,743''N); the third site in the percolated deposit pond of the landfill (P-03: at 23º28'55,256''S and 51º57'31,171''N) (Figure 1).

Collections were undertaken at the streamlet surface with a flask immersed 10 to 15 cm, with its mouth placed opposite the current. Leach samples were retrieved by a submersed cylindrical collecting recipient locked to a 1.5 L plastic bottle by an iron rod.

Table 1 shows the evaluated parameters and methods used.

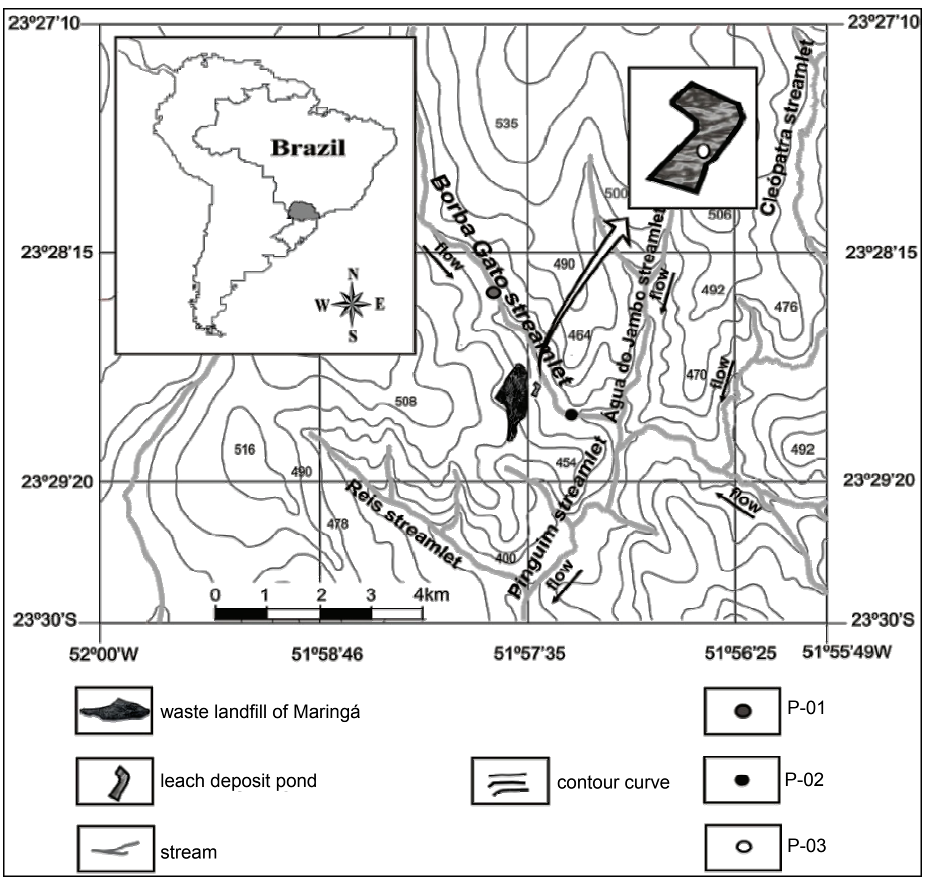

Figure 1. Site of the area under analysis (12/14/2005).

Table 1. Parameters and methods of the physic-chemical analyses for the study of percolate of the waste landfill and of the water from the Borba Gato streamlet.

Parameter	Method of analysis	Parameter	Method of analysis
Total Chloride	method 4500 Cl^- B[1]	Total suspended solids (TSS)	method 2540 D [1]
True color	method 8025[2]	Total dissolved solids (TDS)	method 2540 D [1]
Biochemical Oxygen Demand of 5 days (BOD_5)	method 5210 B[1]	Sulfide (S^{2-})	method 8131 [2]
Chemical Oxygen Demand (COD)	method 5220 B[1]	Total sulfate SO_4^{2-}	method 8051 [2]
Ammoniacal nitrogen ($N-NH_3$)	method 4500-NH_3 B e C[1]	Temperature	Mercury thermometer
Organic nitrogen (Norg)	method 4500-Norg B[1 e 3]	Turbidity	Turbidimetric
Nitrate (NO_3-N)	method 8039[2]	Aluminum, copper, iron and manganese	method 3030 E and 3111[1] (samples were filtered)
Nitrite (NO_2-N)	method 8153[2]	Cadmium, chromium, nickel, lead and zinc	method 3030 E and 3111[1]
Dissolved Oxygen (DO)	Electrometric with membrane	Mercury	method 3112 B[1] adapted by the Agro-chemical Lab of UEM
Hydrogenic potential (pH)	Electrometric		

[1]APHA (2005); [2]Hach (2000) and [3]Vogel (2002).

Rainfall data were provided by the climatologic station of the State University of Maringá, Paraná State, Brazil. Further, t test verified whether there were any differences between the sites upstream (P-01) and downstream (P-02) the waste landfill. The following hypotheses were studied for each parameter, with 5% level significant:

H_0: no difference between means of rates of the parameter **i** of P-01 and P-02

H_1: difference exists between the means of rates of parameter **i** of P-01 and P-02,

in which: **i** = total chloride, true color, BOD_5, zinc and mercury. Confidence interval (CI) was undertaken at 95% confidence level for parameters with significant difference.

Results and discussion

Current study shows that rainfall is a hydrological factor that disseminates pollutants in the water body due to the lack of dense vegetation or riparian vegetation within the river boundary, with the subsequent discharge of organic and inorganic matter into the streamlet. Rainy period was more intense between September and March 2006 (Figure 2).

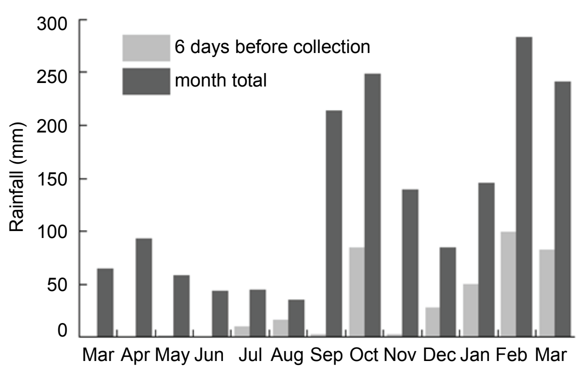

Figure 2. Variation in rainfall level between March 2005 and March 2006.

Results are the following.

Temperature: In most months environmental temperature at P-01 and P-02 was higher than that of the streamlet (Figure 3A). Temperature of leach deposited in the waste pond was higher than that of the environmental temperature between October 2005 and March 2006 (Figure 3B).

According to Gastaldini and Mendonça (2003), temperature affects physical, chemical and biological processes in water bodies and influences the concentrations of several variables. Increase in temperature is followed by an increase in chemical reaction speed and by a decrease in the solubility of gases in water, such as oxygen (O_2), carbon dioxide (CO_2), nitrogen (N_2) and methane (CH_4).

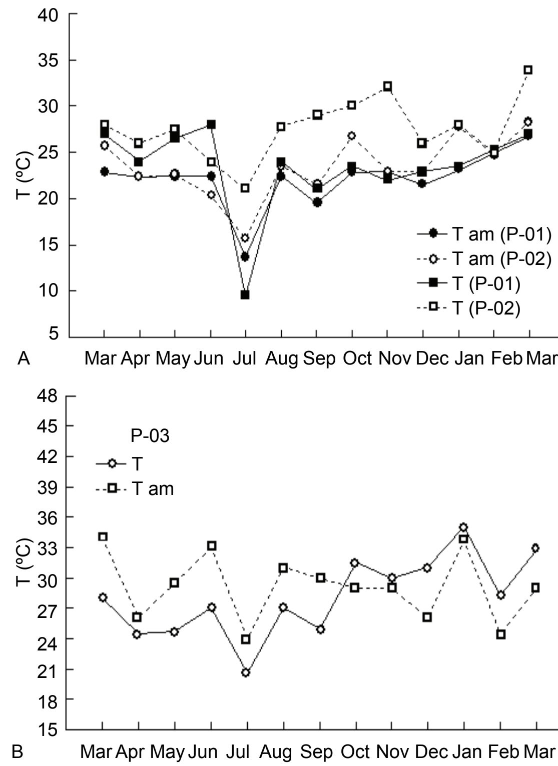

Figure 3. Temporal variation of environmental temperature (T am), water of Borba Gato streamlet (T) at sampling sites and leach deposited in the waste pond.

Dissolved oxygen: Figure 4A shows that dissolved oxygen decreased during the months, albeit within the fresh water quality Standards established Conama 357/2005 (Class 2) (BRASIL, 2005). The decrease may be related to rain intensity which transported a greater volume of inorganic material to the streamlet bed, with a decrease in dissolved oxygen and rise in temperature which reduced gas solubility and increased the oxidation process of the transported material. Statistical analysis showed that mean dissolved oxygen at P-01 and P-02 did not differ significantly ($t = -1.166$; $p = 0.248$).

There was less concentration of leach in the pond, ranging from not detected amounts to 6.42 mg L^{-1} O_2 (Figure 4B). It is possible that oscillation occurred due to the increase in organic material in the months with low oxygen concentrations.

Atmosphere and photosynthesis are the main oxygen sources for water. On the other hand, losses occur by the decomposition of organic matter, respiration of water organisms and oxidization of metallic ions, such as iron and manganese (ESTEVES, 1998).

pH: Sampled sites in the streamlet registered pH levels within the fresh water quality standard stipulated by Conama 357/2005 (Class 2) (Figure 5A). Mean pH difference was significant ($t = 2.680$; $p = 0.009$; CI = 0.045 to 0.309), or rather, pH at P-02 was higher than that of P-01, with 95% certainty that P-02 differed from P-01 at a confidence interval (CI) between 0.045 and 0.309.

Moreover, pH of leach deposited in the pond was alkaline and within the effluent discharge standard stipulated by Conama no. 357/2005 (Figure 5B).

True color: Although true color oscillated, it maintained itself within established standards in most months (75 mg L^{-1} Pt), following Conama 357/2005, with the exception of March 2006 at P-01 due to heavy rains minutes before the collection and in P-02 in February 2005 and March 2006 (Figure 6A). There were no significant differences by t test in the levels of true color at P-01 and P-02 ($t = 1.389$; $p = 0.169$).

True color of P-03 had its highest peak in November (Figure 6B) possibly due to the deposition of building residues around the pond to increase its depth. There was a decrease in concentration in March 2006 probably due to building leftovers deposited on the road leading to the pond to minimize the percolate flow. Media reports revealed the possibility of flooding because of rain intensity.

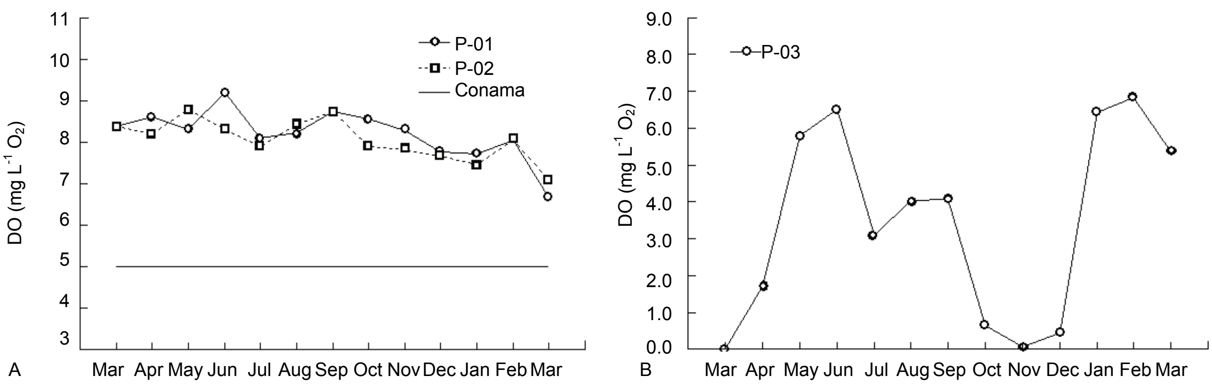

Figure 4. Temporal variation of dissolved oxygen (DO) at sampling sites in Borba Gato streamlet and leach in the pond.

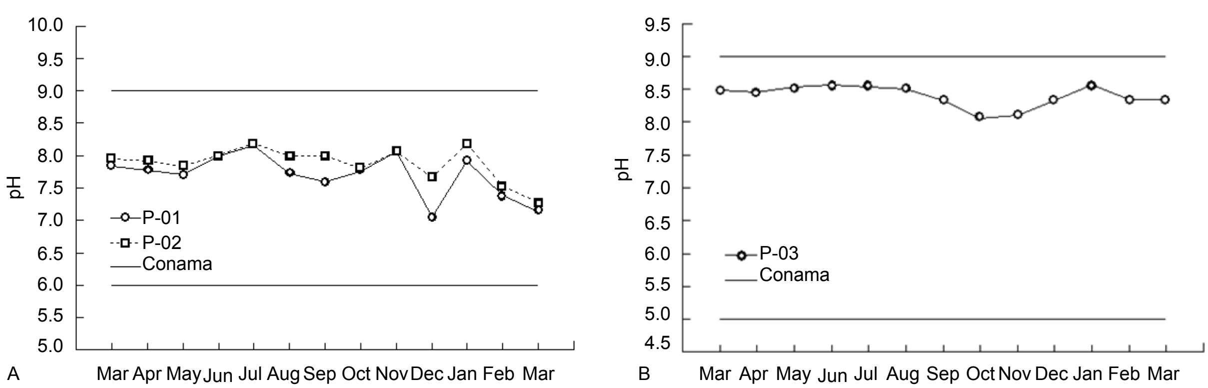

Figure 5. Temporal variation of pH at sampled sites in the Borba Gato streamlet and leach deposited in the waste pond.

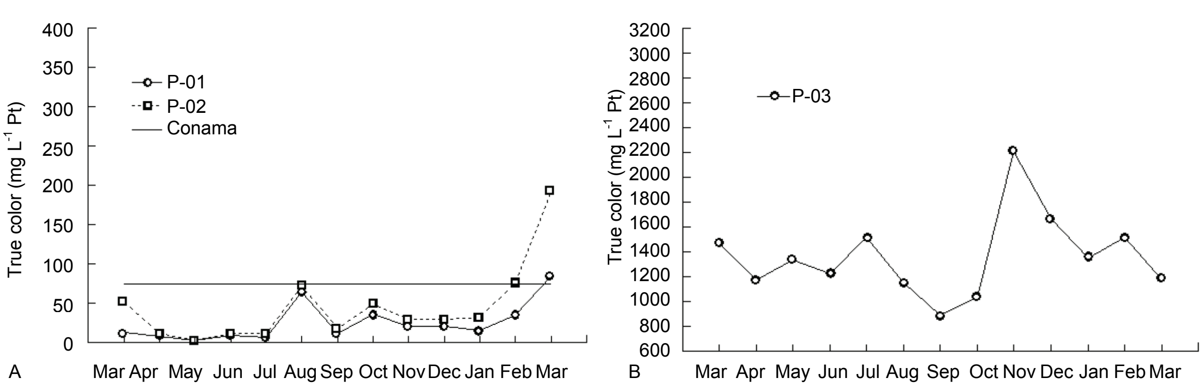

Figure 6. Temporal variation of true color at sampled sites of Borba Gato streamlet and leach deposited in the waste pond.

Total chloride: Concentrations of chloride in the waste pond were lower than 250 mg L^{-1}, the limit established by Conama 357/2005 (Figure 7A). There was significant difference ($t = 9.165$; $p = 0.000$; CI = 7.52 and 11.78 mg L^{-1}) in chloride concentration between P-01 and P-02.

Chloride concentrations in leach increased successively throughout the first six months of current research (dry season), with a decrease in September and October, and a rise in November (Figure 7B).

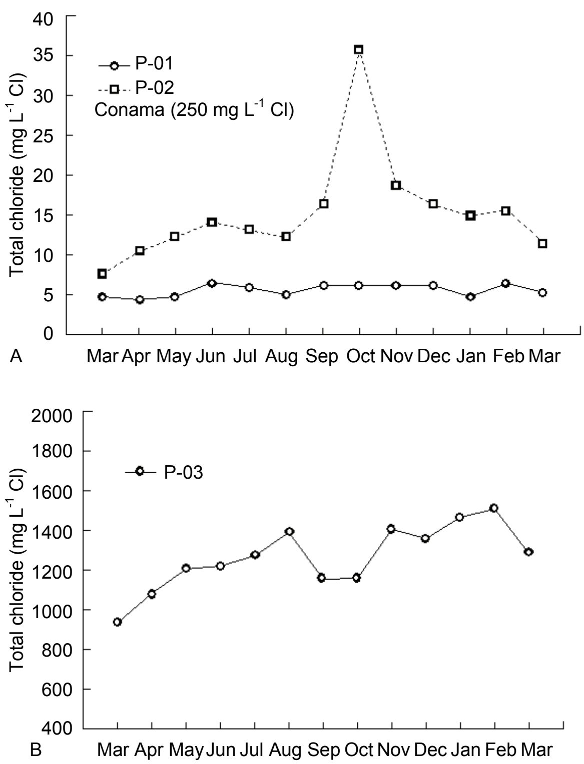

Figure 7. Temporal variation of total chlorate at sampling sites of Borba Gato streamlet and leach in the waste pond.

Carmo et al. (2005) report that possible sources of chloride in water bodies are sewages and fertilizers. However, current study pinpoints leach as possible source of chlorate downstream the waste landfill. It may be noted that peak in October at P-02 occurred due to the placing of two more drain pipes in the landfill waste pond in the direction of the stream, at the beginning of October.

Organic and ammoniacal nitrogen: During monitoring P-02 had the highest oscillations in organic nitrogen, such as ammoniacal nitrogen (Figure 8A). Statistical analysis showed that organic nitrogen and ammoniacal nitrogen levels were significantly different, ($t = 2.770$; $p = 0.008$; CI = 0.75 and 4.80 mg L^{-1} N) and ($t = 2.744$; $p = 0.009$; CI = 0.62 and 4.01 mg L^{-1} N), respectively, between sites P-01 and P-02.

When leach in the landfill waste pond is taken into account, the ammoniacal nitrogen at P-03 was above discharge standards established by Conama 357/2005 (Figure 8B). Consequently, treatment of the effluent prior to discharge into the environment is mandatory. It must be emphasized that the highest peak in ammoniacal and organic nitrogen downstream the landfill occurred during the month when two more drainage tubes were placed in the percolate pond. Leach is therefore contributing towards the pollution of Borba Gato streamlet.

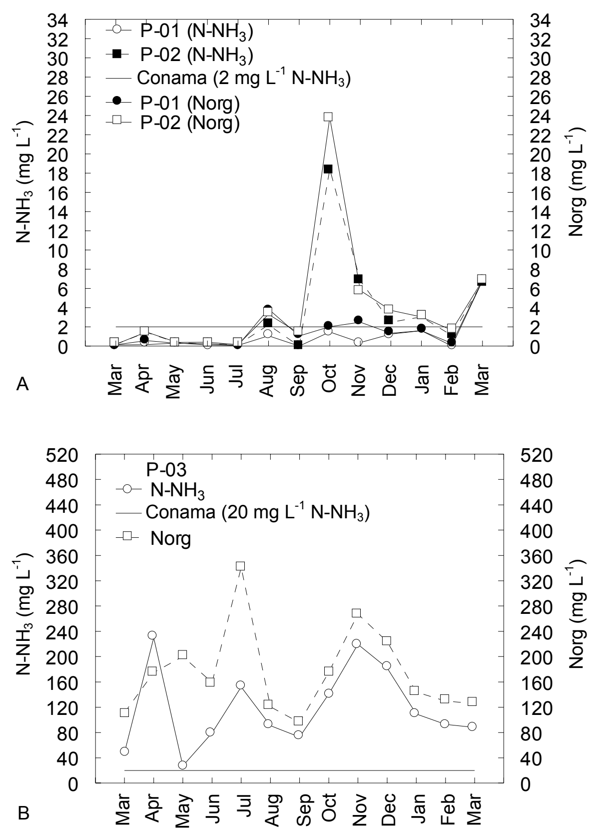

Figure 8. Temporal variation of organic nitrogen (Norg) and ammoniacal nitrogen ($N-NH_3$) at sampling sites on the Borba Gato streamlet and leach in the waste pond.

Nitrite and Nitrate: Whereas nitrite oscillations levels were higher contents than those stipulated by Conama no. 357/2005, nitrate was found within the specifications of Conama (Figure 9A). Differences between P-01 and P-02 in nitrate ($t = 2.542$; $p = 0.014$; CI = 0.14 and 1.17 mg L^{-1} N) and in nitrate ($t = 3.297$; $p = 0.002$; CI 0.23 and 0.93 mg L^{-1} N) rates were statistically significant. Nitrite levels in the leach ranged between 15.00 and 40.00 mg L^{-1} N; however, nitrate contents ranged between 25.00 and 54.00 mg L^{-1} N (Figure 9B).

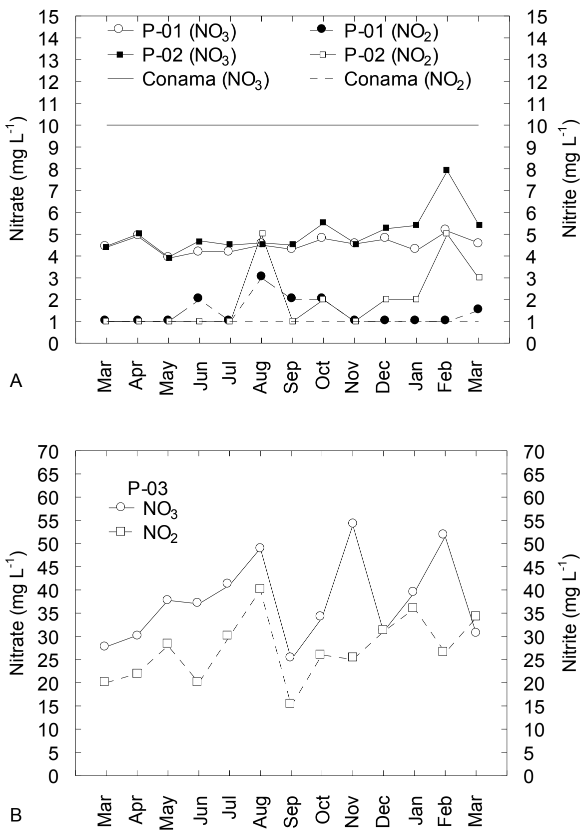

Figure 9. Temporal variation of nitrite (NO_2) and nitrate (NO_3) at sampling sites of the Borba Gato streamlet and leach deposited in the waste pond.

According to Esteves (1998), nitrite in high concentrations is toxic to most water organisms. Baird (2002) reports that there has recently been a great concern with the increase of nitrate ion rates in fresh water, especially in rural areas. This is due to the fact that the main source of the ion is the discharge from agricultural land to rivers and streams. The statement is actually a source of preoccupation since in the area under analysis there is no other drinking water source for the inhabitants who retrieve water from wells and springs.

Oxygen demand: Biochemical (BOD_5) and chemical (COD) oxygen demand varied at the sites (Figure 10A). However, statistical tests revealed that there was no significant difference between results of the two analyzed sites for BOD_5 ($t = -0,194$; $p = 0.847$) and COD ($t = -0.067$; $p = 0.947$).

Variations in the organic matter of the leach showed that COD had higher rates in November and BOD_5 in December (Figure 10B).

Low source of organic pollution has been reported in the region of the stream under analysis with the exception of March 2006 when heavy rainfall occurred immediately before collection at P-01. Concentrations of BOD_5 close to 5 mg L^{-1} O_2 occurred in June, although low levels of organic and ammoniacal nitrogen during this month showed that pollutants were not discharged at a recent date (near the place). According to Gastaldini and Mendonça (2003), water with high concentrations of organic and ammoniacal nitrogen and small concentrations of nitrates and nitrites cannot be taken as safe due to recent pollution. On the other hand, samples without organic nitrogen or without ammoniacal nitrogen and with slight traces of nitrate may be relatively safe due to the fact that nitrification has already occurred and pollution was not a recent event.

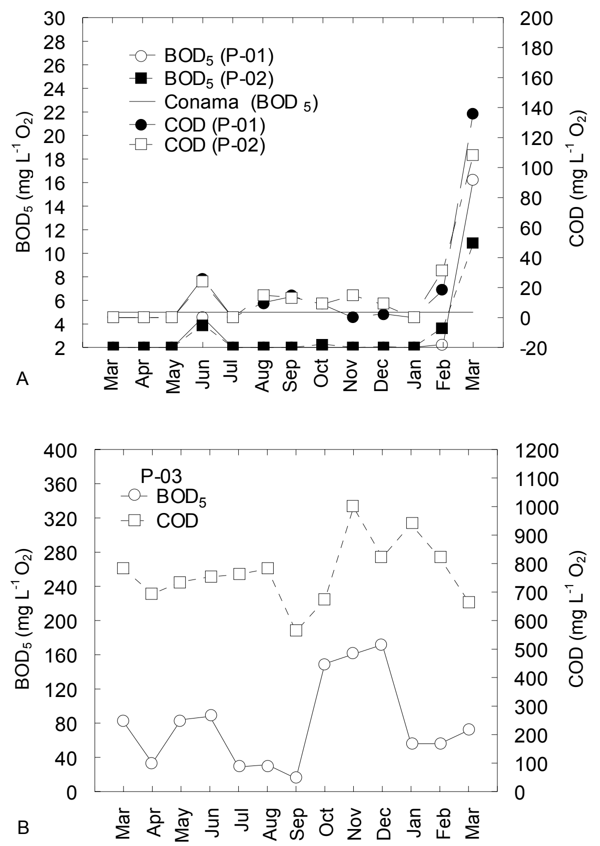

Figure 10. Temporal variation for chemical (COD) and biochemical (DBO_5) oxygen demand at sampling sites in the Borba Gato streamlet and the leach deposited in the waste pond.

Total solids: P-02 did not have the same profile as P-01 with regard to suspended solids perhaps due to modifications undertaken by the Municipal Public Works Department at the base of the landfill and around the waste pond during May and November, which discharged more suspended solids in the stream and in the pond (Figure 11).

Level differences in suspended solids between sampling sites was significant ($t = 2.182$; $p = 0.032$; CI = 0.29 and 6.33 mg L^{-1}); similarly with regard to total dissolved solids ($t = 5.905$; $p = 0.000$; CI = 37.44 to 75.55 mg L^{-1}). It should be emphasized that total dissolved solids were within the maximum limits of standard water quality (500 mg L^{-1}) established by Conama 357/2005.

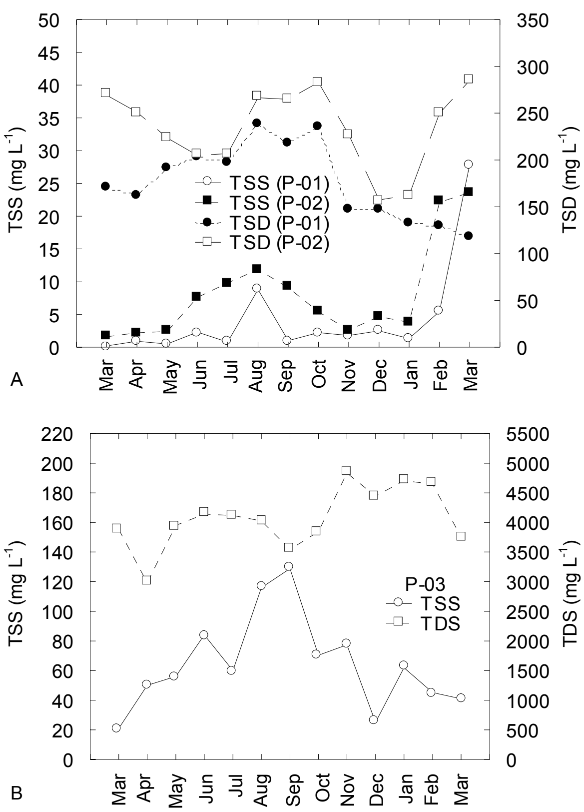

Figure 11. Temporal variation of total suspended solids (TSS) and total dissolved solids (TDS) of sampling sites in the Borba Gato streamlet and leach in the waste pond.

Increase in the suspended solids concentrations in March 2006 in the stream was due to heavy rainfall immediately before collection. Peak during August at P-01 may be due to the end of the wheat harvest and the start of soil preparation for the planting of soybeans, corn or cotton. In fact, the soil was fallow and rains transported a great concentration of organic and inorganic material to the streamlet.

Sulfate and sulfide: Highest level of sulfur were detected as oxides, or sulfates. However, sites P-01 and P-02 had concentrations within the maximum sulfate limit stipulated by Conama 357/2005 (250 mg L^{-1} SO_4^{-2}) (Figure 12A). Statistical analysis showed that mean difference of total sulfate between P-01 and P-02 was significant ($t = 2.808$; $p = 0.007$; CI = 0.43 to 2.57 mg L^{-1} SO_4^{-2}); it was also significant for sulfide too ($t = 3.237$; $p = 0.002$; CI = 0.002 to 0.011 mg L^{-1} S^{-2}).

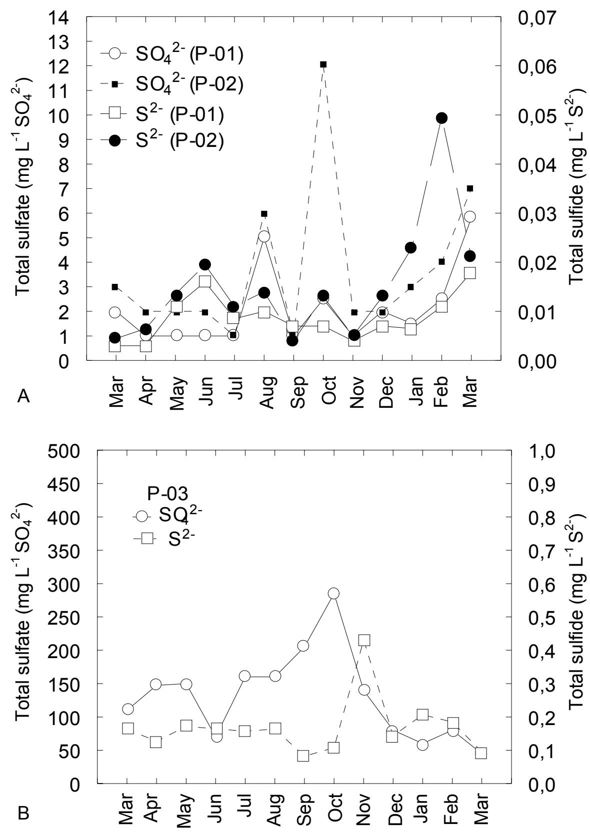

Figure 12. Temporal variation of total sulfate (SO_4^{-2}) and sulfide (S^{-2}) at sampling sites in the Borba Gato streamlet and in the leach deposited in the waste pond.

Total sulfate levels in the leach deposited in the landfill waste pond varied between 45.00 and 285.00 mg L^{-1} SO_4^{-2}, whereas sulfide had variations between 0.08 and 0.43 mg L^{-1} S^{-2} (Figure 12B). Sulfide concentrations in P-03 were within the limits of the effluent discharge standards (1.0 mg L^{-1} S^{-2}) established by Conama 357/2005.

High sulfate levels at P-02 during October were due to the placing of two drainage tubes in the landfill waste pond for leach deposits. During the same month, the effluent had the highest sulfate concentration.

Turbidity: Although turbidity concentrations at P-01 and P-02 oscillated, both sites were within the limits of water quality according to Conama no. 357/2005 (Figure 13A). Statistical analysis showed that P-01 and P-02 differed significantly ($t = 3.247$; $p = 0.002$, CI = 1.42 and 6.05 UNT). Oscillations ranging between 1.40 and 5.76 UNT in the turbidity of the percolate material deposited in the waste pond were reported (Figure 13B).

Highest turbidity levels occurred at P-02 in February, similar to what occurred with suspended solids, true color, sulfide, nitrite and nitrate.

This phenomenon was probably due to heavy rains which discharged a greater flow of leach in the streamlet.

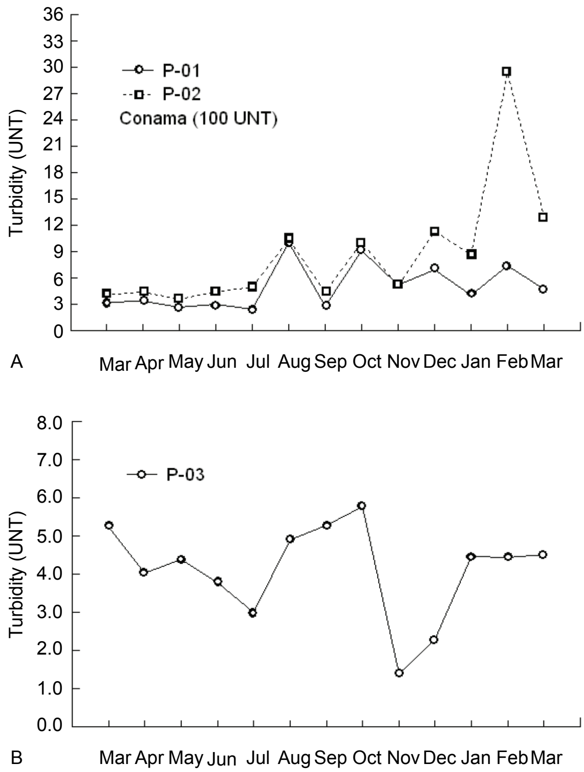

Figure 13. Temporal variation of turbidity at sampling sites on the Borba Gato streamlet and the leach deposited in the waste pond.

Dissolved Aluminum, Copper and Iron: Variations occurred in dissolved aluminum, copper and iron (Figure 14), with concentrations above the fresh water quality limits established by Conama no. 357/2005 (Class 2) occurring only during some months. Dissolved aluminum rates in the percolate were above the effluent discharge standard during September.

Dissolved aluminum levels revealed significant differences between P-01 and P-02 ($t = 2.493$; $p = 0.016$; CI = -0.047 to 0.430) which was probably due to the flow of leach of the landfill waste pond polluting the water of the streamlet. Significant differences did not occur with regard to dissolved copper ($t = 0.701$; $p = 0.485$) and dissolved iron ($t = 1.769$; $p = 0.081$).

Cadmium, Chromium, Mercury, Nickel, Manganese, Lead and Zinc: During some months, cadmium, chromium and mercury levels and nickel, manganese, lead and zinc, during most months, at sampling sites on the streamlet were above the water quality limits established by Conama 357/2005. Levels of these elements in the percolated material were within the effluent discharge limits established by Conama 357/2005 (Figure 15).

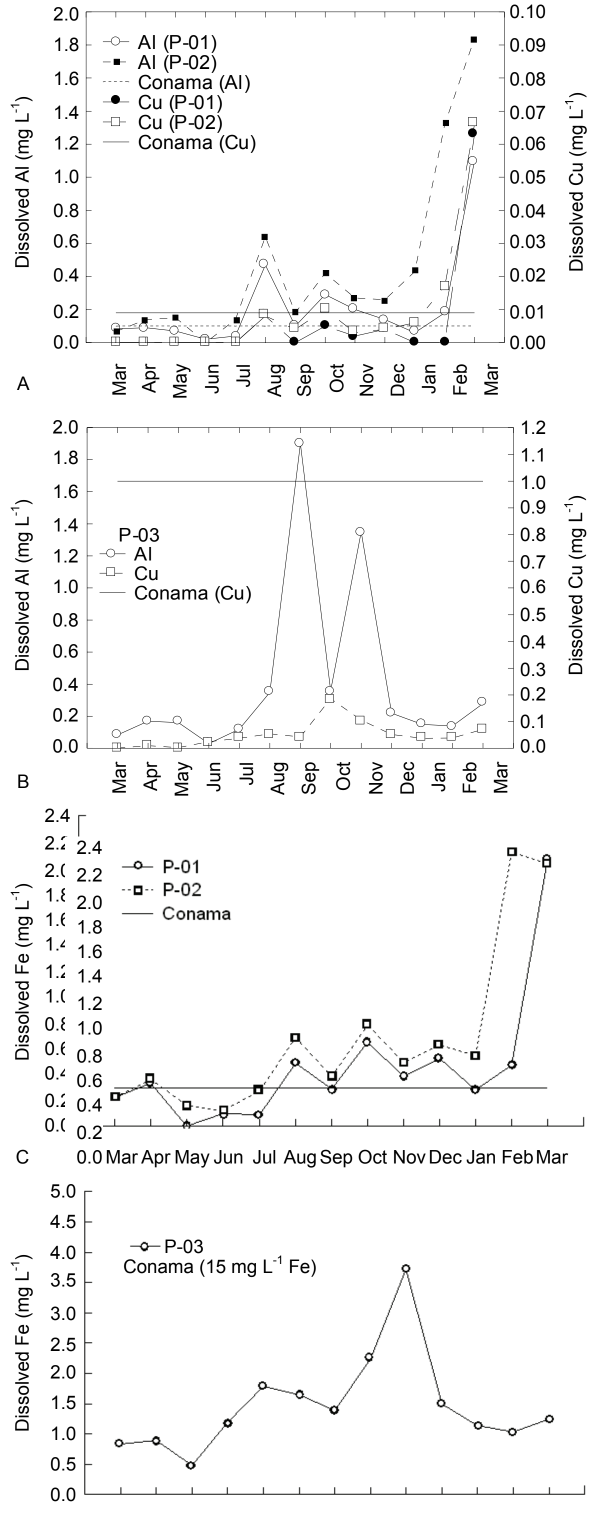

Figure 14. Temporal variation of dissolved aluminum (Al), copper (Cu) and iron (Fe) at sampling sites in the Borba Gato streamlet and the leach deposited in the waste pond.

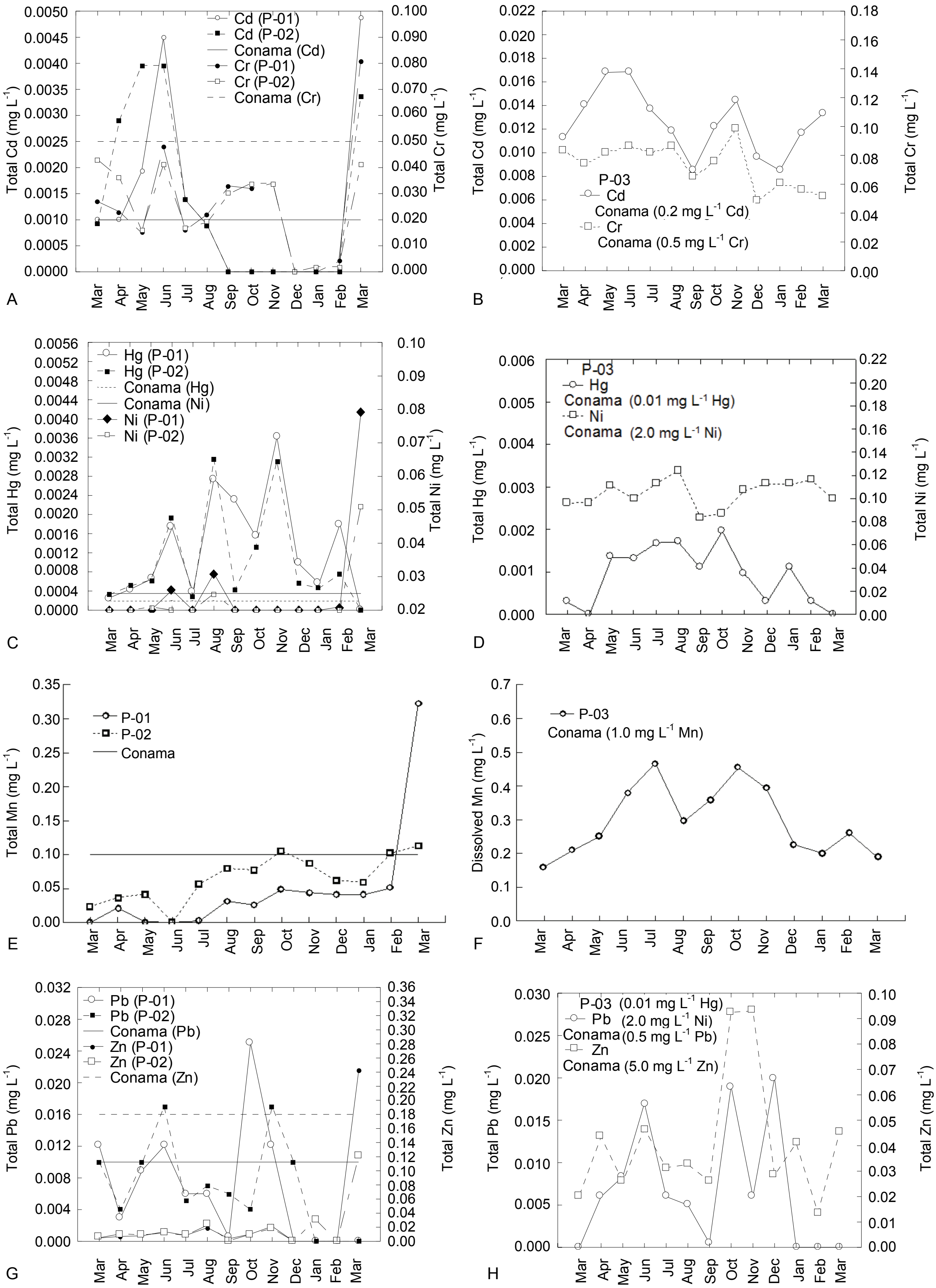

Figure 15. Temporal variation of total cadmium (Cd), chromium (Cr), mercury (Hg), manganese (Mn), nickel (Ni), lead (Pb) and zinc (Zn) at sampling sites in Borba Gato streamlet and the leach in the waste pond.

Statistical analysis showed that cadmium levels did not have any significant differences between the sampling sites on the streamlet ($t = -0.409$; $p = 0.683$), as occurred with chromium ($t = -0.370$; $p = 0.712$), mercury ($t = -1.138$; $p = 0.259$), nickel ($t = -0.311$; $p = 0.757$), lead ($t = 1.283$; $p = 0.204$), zinc ($t = -0.558$; $p = 0.579$) and manganese ($t = 1.426$; $p = 0.160$). However, the latter element did not have any significant difference due to high concentrations at P-01 in March 2006, which increased the variation range due to heavy rainfall prior to collection at this site.

Greatest concern lies with mercury among the trace elements under analysis, since many researchers, such as Baird (2002), Ravichandran (2004), Mirlean et al. (2005), consider it the most toxic within the water environment. Further, mercury is a bio-accumulating element. Mercury pollutant source in the streamlet may have been discharged throughout the streamlet's course since in June an organic discharge occurred and pollution was not limited to the site. Further, high levels of cadmium, chromium, nickel and lead were also reported.

Further, since the P-01 region is an agricultural area, soil may have retained trace elements, with the exception of cadmium, in agricultural defensive products or in fertilizers which were leached and discharged into the streamlet during the rainy period. In fact, the second largest levels of mercury, nickel and zinc were registered during August, precisely at the end of the wheat harvest and the preparation of soil for sowing. In other words, the soil was exposed to leaching. According to Bisinoti and Jardim (2004), soils have a high capacity in retaining and storing mercury due to the strong links of this element with carbon. Mercury is thus released from the soil by the rains and discharged into the streamlet. In fact, a series of factors may affect the dynamics of mercury.

According to Silva and França (2004), agricultural activities and the maintenance of the waste pond close to water courses and the conditions in which such activities develop trigger risk factor involving contamination and pollution of the region's water resources. According to Andreoli et al. (2003), water, as a rule, will always contain impurities and practically pure water is not extant in nature. Consequently, its composition depends on the environment and its assimilation of different pollutants.

Conclusion

The streamlet area under analysis was impacted, which was probably due to its characteristics as an agriculture land and to inadequate deposition of urban wastes in the municipality of Maringá, Paraná State, Brazil. It should also be emphasized that in the area close to site P-01 the streamlet margins have only rare vegetation and that during the rainy season inorganic compounds, such as aluminum, iron and manganese, inherent to the composition of the soil surface, were discharged in great amounts

Since the streamlet reveals parameters outside the fresh water quality standards of Conama's Class 2 features, the streamlet within this region should be characterized as exclusively for landscape, or rather, the water body should be classified as Class 4 according to Conama no. 357/05. A study on the entire basin of the Borba Gato streamlet should be undertaken so that pollution sources could be monitored and detected. Further, a management project should be instituted for the protection of the fauna and the flora of this water environment and an appropriate aim for the water course should be determined.

Besides the urgent need for efficient treatment of the effluent produced in the landfill waste pond in Maringá has been demonstrated, there is also evidence that leach has polluted the Borba Gato streamlet.

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