SOUTHERN BRAZILIAN JOURNAL OF CHEMISTRY
SOUTH. BRAZ. J. CHEM., Vol.13, No. 13, 2005

POLLUTION EFFECTS ON THE ENVIRONMENT, MACROPHYTES AND FISHES IN THE SAPUCAIA STREAM, GUAÍBA HYDROGRAPHIC BASIN, RS, BRAZIL.

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ABSTRACT

This paper shows the results of air, water and sediment quality of Sapucaia stream, which belongs to Guaíba Hydrographic Basin, in the State of Rio Grande do Sul, Southern Brazil. The correlations among the concentrations of Al, Cu, Fe, Mn and Zn, present in the atmosphere, water and sediments, and their bioaccumulation in macrophytes are deteminated. Different degrees of pollution are characterized through the study of the oxidative damage in fishes. The results indicate metal accumulation in macrophytes and fishes.

RESUMO

Este trabalho apresenta os resultados da qualidade do ar, da água e de sedimentos do Arroio Sapucaia, que pertence à Bacia Hidrográfica do Guaíba, Estado do Rio Grande do Sul, Sul do Brasil. São determinadas as correlações entre as concentrações de Al, Cu, Fe, Mn e Zn, presentes na atmosfera, na água e em sedimenentos, e sua bioacumulação em macrófitas. Através do estudo dos efeitos oxidativos em peixes são caracterizados diferentes graus de poluição. Os resultados indicam uma acumulação de metais em macrófitas e em peixes.

KEY WORDS: environmental survey, fishes, macrophytes, micro and macro elements, pollution

DOI: 10.48141/SBJCHEM.v13.n13.2005.30_2005.pdf

INTRODUCTION

The quality of water and air in the Sapucaia Stream area, located in the State of Rio Grande do Sul, Southern Brazil, present several degrees of alterations, which affect the life quality of the local population. In this area, air emissions include inorganic and organic gases and suspended solid particles, mainly heavy metal, released by different sources like industries, vehicle traffic, soil erosion, withdrawal of covering plants.

The Sapucaia stream (Figure 1) crosses, in its initial reaches, low environmental impacted areas. In the pursuing of its course, this impact increases until reaching higher a dammage index in its final course, where it discharge its waters in the Sinos River, a tributary of Guaiba hydrographic basin, the main hydrografic basin of the State, water supplier of the city of Porto Alegre (1,500,000 inhabitants). The diverse regions of this basin present different impacts due to the atmospheric fallout and runoff of residues, reflecting in the quality of water, sediments, living organisms of the stream and human population that inhabits the area of the hydrografic basin[1] .

Vegetation, through air absorption, may accumulate trace elements, which may be transferred to animals and human groups through the trophic chain[2]. This accumulation can increase in some seasons of the year[3].

Alterations in the bioaccumulations of some elements in the macrophytes *Ludwigia sp*, *Ludwigia longifolia* and plants like *Paspalum pumilium* and *Acacia niger*, occur in sediment and water, among other parameters, with variations of pH. Usually, iron concentration is high in acid environment while manganese concentration is low[4].

An ecological evaluation of pollutant effects on organisms must include biological, physico-chemical and toxicological analysis. This implies that an analysis of heavy metals or organic residue effects in water must include a complete study of the abiotic conditions[5]. Data organization concerned with pollution and its effects is necessary for an environmental management program.

In this paper, correlations among the concentrations of five elements present in the atmosphere, water and sediments, with their bioaccumulations in vegetation and fish are evaluated. In a previous work[6] the concentrations of 12 elements in the atmosphere of this area were measured and their correlations with bioaccumulation in water, sediments, plants and fishes were presented.

MATERIALS AND METHODS

Area description. Sapucaia stream, tributary of Sinos River, with a length of 25 km, is located between 29° 45' and 30° 00' LS and 51° 15' and 51° 00' LW, covering an area of 129.57 km^2 in the metropolitan region of Porto Alegre (Figure 1). In upper order reaches, the hydrographic basin presents an area with low populational density and agricultural features where small farming activities of low environmental impact prevail. In intermediate areas, there are urban zones of high populational density and a large number of industries (cement, metal-mechanics, oil refinery, and chemical). In this area, urban solid wastes are deposited causing a high environment impact. Also in this region, two principal highways, namely RS 118 and BR 116, with intense traffic of vehicles (around 120,000 vehicles per day) cross the stream. This region is characterized by a high environmental impact. In the final reaches, near the Sinos River, rice culture areas are observed in both edges of the stream[1].

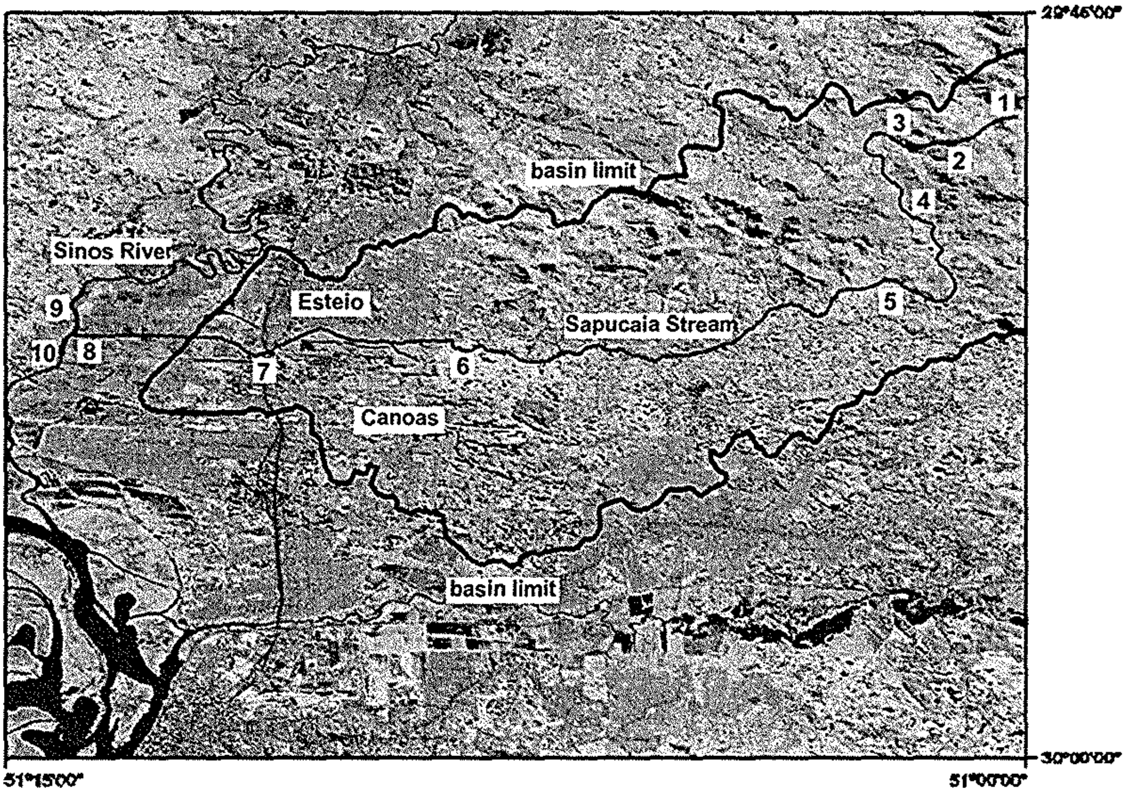

Figure 1. Sampling Points on Sapucaia Stream

Sampling procedures. Eight sampling points were selected in Sapucaia Stream (Figure 1) to collect water, sediment, macrophytes and fishes.

The first was placed near one of the upper level reaches, at 29°49´12,9´´S and 51°49´29,0´´W (135m altitude), in the rural region of Santa Tecla, City of Gravataí, where the environmental impact is relatively low. The second was located at the beginning of a wetland area with cattle breeding activities, at 29° 49´45,9´´S and 51°02´15,7´´W (71m altitude). Sampling point 3 was chosen after the wetland, where the main source of contamination is mining activity (basalt and sandstone-quarry), 29° 49´48,0´´S and 51°02´37,8´´ W (68m altitude). Sampling point 4 was placed in an area with little agricultural activities. In this sampling point, named Sta. Tecla, was placed a high volume sampler (HI- VOL) to collect the total suspended particles (TSP) in the atmosphere, at 29° 50´30.1´´S and 51°02´57.9´´W (altitude 48m).

The fifth point was located after a solid waste deposit facility in Santa Tecla. Afterwards, the stream drains urban areas of the cities of Sapucaia and Esteio cities, with an invader population on the waterfront, at 29° 51´59.1´´S and 51°03´19.4´´W (37m altitude). In the City of Esteio, many industries (including refinery, petrochemical, chemical, cement) and a solid waste recycling plant, which release pollutant materials in the stream, are present. Sampling point 6 was located in this region. Sampling point 7 was located near the highway BR 116, with an intense traffic. Finally, sampling point 8 was placed in the rice culture area just before the Sapucaia stream empties into the Sinos River. Samples were also collected in Sinos River on both sides of the stream mouth (upper head and lower level), to study the interference in Sinos biota (sampling points 9 and 10). Two other HI-VOL samplers were located near to sampling station 6, named Campus, and in a petrochemical plant, named Industrial Zone, (near to sampling station 8).

Water, sediments and macrophytes samples were collected at every sampling point in the cold season (Autumn and Winter, 2001) and in the hot season (Spring, 2001 and Summer, 2002).

Analytical procedures. Analysis of water physical and chemical parameters like pH, saturation percentage and dissolved oxygen (DO), electrical conductivity (EC), hardness, chlorides, alkalinity, organic matter (OM), total nitrogen and phosphorus was made during the year of 2001. The analytical procedures measured five elements (aluminum, copper, iron, manganese, and zinc) content in water. All the determinations were carried according to the Standard Methods present in Standards of American Public Health Association[7].

Analysis of pH and of macro nutrients (nitrogen, total phosphorus and potassium) were performed in dry sediment samples according to Tedesco[8] and Vandecasteele[9].

The HI-VOL samplers operating with a flow rate between 1.1 and 1.7 m^3/min were used to collect total suspended particles in the atmosphere with aerodynamic diameters up to 25-50 μm. Measurements were conducted from March, 2001 to March, 2002.

The filters with the collected particles, after digestion with a 1:1 HNO_3 – HCL mixture (strong digestion), were assayed to determine the concentrations of the chemical elements mentioned before. Mild digestion was used to determine soluble metals in water and in sediments and strong digestion was used to determine total metals in macrophytes and in fishes[3, 10,11].

The analysis of the same elements previously studied in water, air and sediments were performed in a macrophyte, the Commelinaceae *Tripogandra diuretica* and in fishes, Jundiá, *Rhamdia quelen*.

Fish were collected at sampling points 4 and 8, with low and high environmental impacts, respectively, in winter (July, August, 2001) and spring (October, November, 2001). Gills, livers and a piece of muscle of the fishes were collected and were frozen in liquid nitrogen. The samples were kept under dry ice during the transportation to the laboratory. After, the tissues were tritured and blended with a phosphate buffer and centrifuged with 3000 rpm for 10 min at 2° C. Some aliquots of the supernatant material were removed for the TBARS (reactive substances to the thiobarbituric acid) determinations and protein measurements[12]. A statistical analysis was carried out using the "t" Student Test, with 5% for the significance level.

RESULTS AND DISCUSSIONS

The measured pH indicates that, in both seasons, water was slightly basic in the sampling points 1 to 8, and almost neutral in sampling points 9 and 10 (Tables 1 and 2). For the sediments, pH was nearly neutral, except at the points 4 and 5, where it is nearly acid. The sediments were almost neutral at the sampling points 1, 3 and 8 (Tables 1 and 2).

Dissolved oxygen (DO) was very low, even near to the head stream, especially in the cold season (Table 1). During the hot season, the thinner water blade leads to an increase of the concentration of organic mater, resulting in the decrease of the DO concentrations, especially at point 2, wetland areas, and in the final reaches. At sampling points located in areas with great environmental impact, from 4 to 10, very low values for DO were found, when compared to the points near the head stream. The fluctuation of the DO values is linked to the release of pollutants (waste water, industrial sewage) from the urban and the industrial areas.

The higher values of alkalinity, at the head stream points, decrease at the intermediate regions and again become high near the mouth zone (Tables 1 and 2). Phosphorus, electrical conductivity, organic matter and chlorides show a regular increase from the head steam to the mouth zones. Hardness and total nitrogen show great variability among the points(Tables 1 and 2).

Interference in the water quality of Sinos River is indicated by the alterations of the physico-chemical parameters from sampling point 9 (located in the Sinos river, in the upper level of the stream mouth) to point 10 (located in the lower level of the stream mouth).

The geometric means, maximum and minumum values for the total suspended particles (TSP) are shown in Figure 2.

The maximum values for the TSP concentrations were found in the cold season. This is explained by the thermal inversions characteristic of the atmospheric conditions. Also the prevailing wind direction (northwest) in the winter brought the emissions from a metallurgic industry, located northwest of the intermediate sample point, in the hydrografic basin area. The maximum acceptable value[13] for the geometric means of TSP is 80 $\mu g/m^3$.

Table 1. Average physico-chemical parameters for water and sediment for cold season (winter and autumn, 2001).

Sampling points	Water								Sediment	
	pH	Dissolved Oxygen (mg/l)	Conductivity ($mS.cm^{-1}$)	Hardness (ppm)	Alkalinity (ppm)	Chloride (ppm)	Organic Matter (ppm O_2)	Total P (ppm)	pH	Total N (ppm)
1	7.75	5.3	0.12	42.89	51	Nd	0.96	0.06	7.00	2.73
2	7.70	7.4	0.12	32.99	41	Nd	2.56	0.12	6.60	7.35
3	7.75	5.8	0.14	54.86	60	Nd	1.28	0.09	7.10	-
4	7.54	3.2	0.12	37.90	48	Nd	0.32	0.08	5.83	11.55
5	7.18	3.0	0.48	32.25	32	Nd	0.24	0.13	5.85	7.00
6	7.40	3.1	0.99	25.94	32	Nd	0.32	0.14	6.58	9.80
7	7.44	2.1	0.38	43.88	87	3.5	0.64	0.83	6.52	12.60
8	7.70	1.8	0.45	58.85	85	4.5	0.48	0.74	7.01	19.25
9	7.04	2.0	0.11	30.92	39	Nd	0.28	0.19	6.50	38.50
10	7.04	3.2	0.21	33.91	53	1.0	0.41	0.26	6.59	16.25

Nd.- not determined

Table 2. Average physico-chemical parameters for water and sediment for hot season (spring, 2001 and summer, 2002)

Sampling points	Water								Sediment	
	pH	Dissolved Oxygen (mg/l)	Conductivity ($mS.cm^{-1}$)	Hardness (ppm)	Alkalinity (ppm)	Chloride (ppm)	Organic Matter (ppm O_2)	Total P (ppm)	pH	Total N (ppm)
1	7.35	3.3	0.21	55.83	71	Nd	1.04	0.09	7.25	17.50
2	6.30	2.1	0.11	37.89	45	Nd	3.92	0.24	7.20	50.75
3	7.20	4.3	0.12	50.85	61	Nd	0.96	0.18	7.54	7.00
4	7.20	5.4	0.11	40.88	51	Nd	2.16	0.34	6.58	8.75
5	7.15	4.1	0.23	44.87	66	1.51	5.12	0.35	6.96	19.25
6	6.85	3.5	0.19	32.9	39	1.76	3.84	0.28	7.23	7.00
7	6.60	3.6	0.19	36.89	52	1.99	4.48	0.61	7.52	10.50
8	7.00	3.2	0.21	37.89	53	2.24	4.21	0.82	7.21	138.25
9	7.00	3.3	0.20	38.10	42	1.86	3.12	0.33	6.42	19.25
10	6.85	3.4	0.13	38.88	36	1.74	3.34	0.51	6.20	7.00

Nd.- not determined

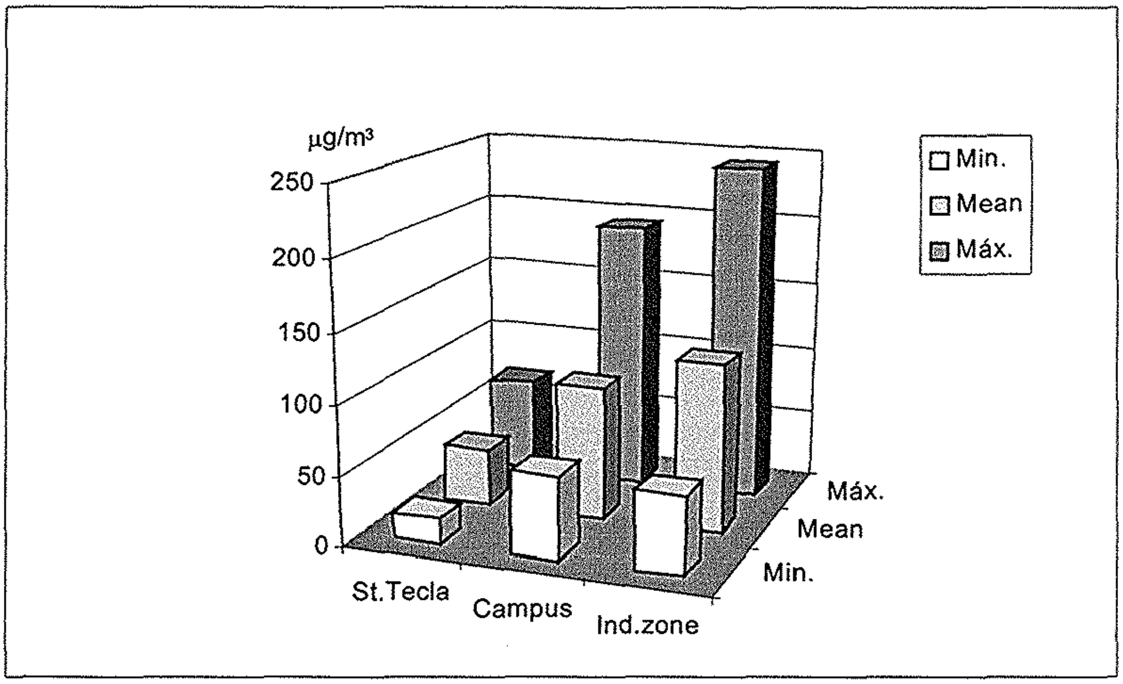

Figure 2. Total suspended particles concentrations in the atmosphere

Figures 3 and 4 show the most representative values for the elements present in the atmosphere.

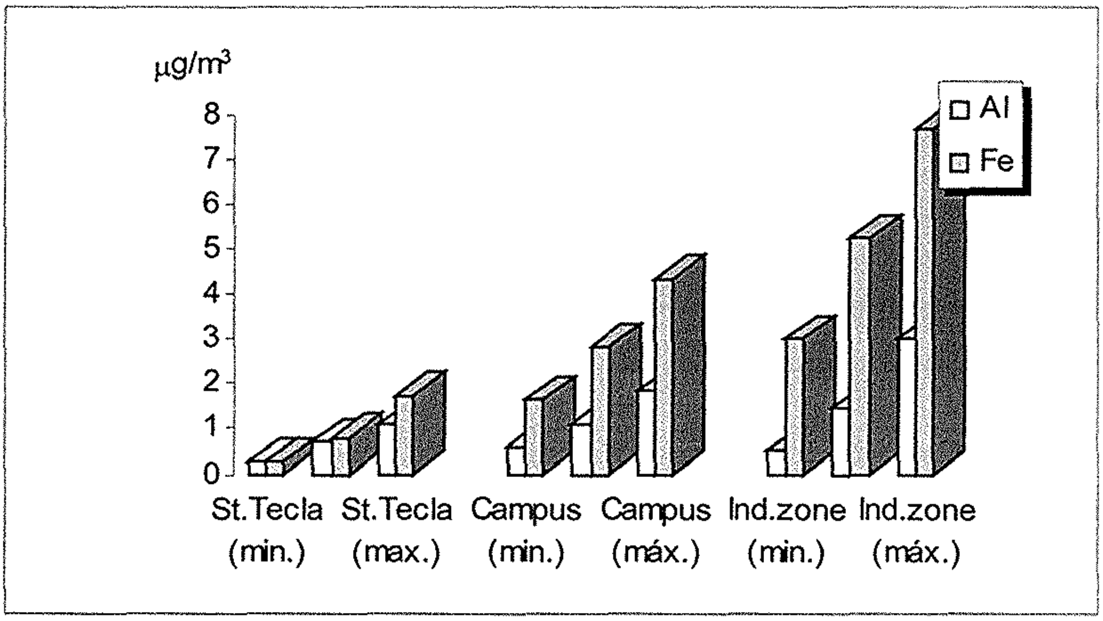

Figure 3. Al and Fe average concentrations in the atmosphere

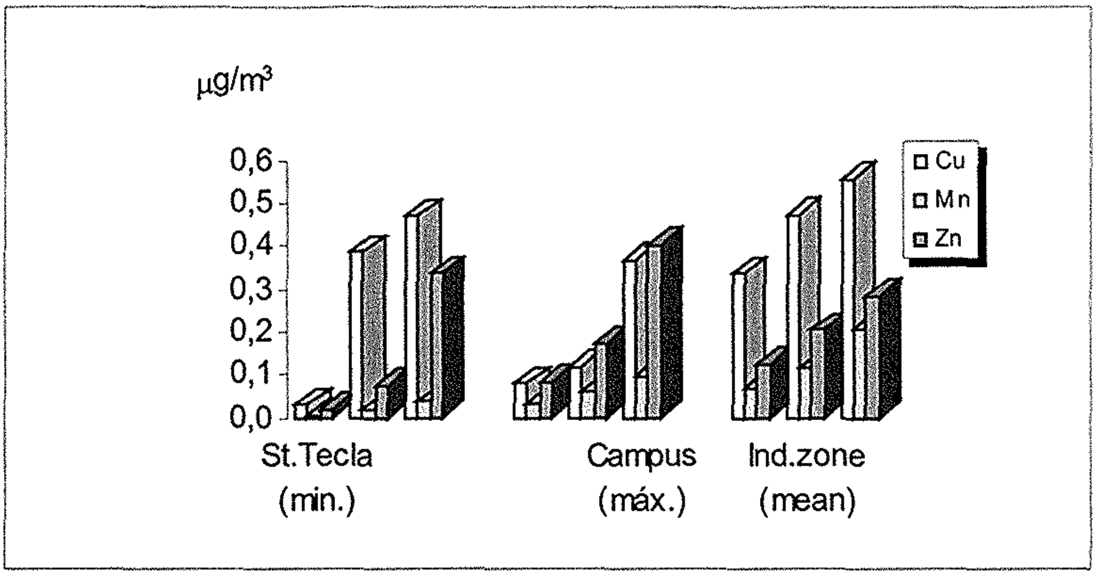

Figure 4. Cu, Mn and Zn average concentrations in the atmosphere

The high concentrations of iron, manganese and zinc, at the intermediary and at the final reaches of the Sapucaia Stream are consequences of the emissions from the industries located in these two zones.

The concentrations of the elements contained in the particles in atmospheric suspension demonstrate a tendency of higher concentrations for the major part of the elements in the industrial region. However, disaggregated particles of uncovered soil areas, agricultural activities and mining around the basin may be considered as great source of aluminum and iron in the atmosphere. The peaks of concentrations for the elements in the urban area (Canoas- Campus) and in the agricultural area (Santa Tecla-Gravataí) are a function of the dispersion of the atmospheric dust.

The significant concentration of copper, in the agricultural area, is caused by its use as fungicidal solution (copper sulfate). Also, this area is near basalt mining activities, a natural source of cooper. Zinc concentrations, in the urban area, are attributed to metal-mechanical and galvanoplasty companies.

The effect of the urban and industrial contamination may be observed by the increase of the concentration of Al, Fe, Cu and Zn (Figures 5,6,7) after point 5 (final reaches area).

These figures also show the filtering action of the wetland area, located at point 2, (where the accumulation of almost all elements is observed) and the reduction of the contamination gradients for water and sediment. At the third point a perceptible reduction of these concentrations occurs, even with the occurrence of sandstone and basalt rocks mining activities in contiguous area, contributing to increase the lixiviated material by rain and wind for the stream´s bed.

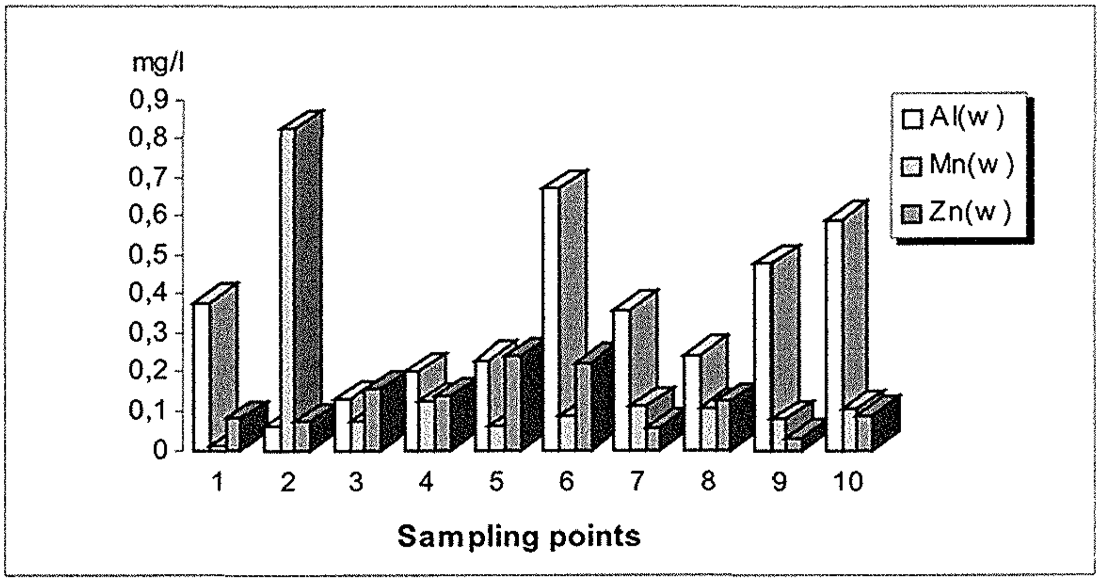

Figure 5. Al, Mn and Zn concentrations in water at different sampling points(winter)

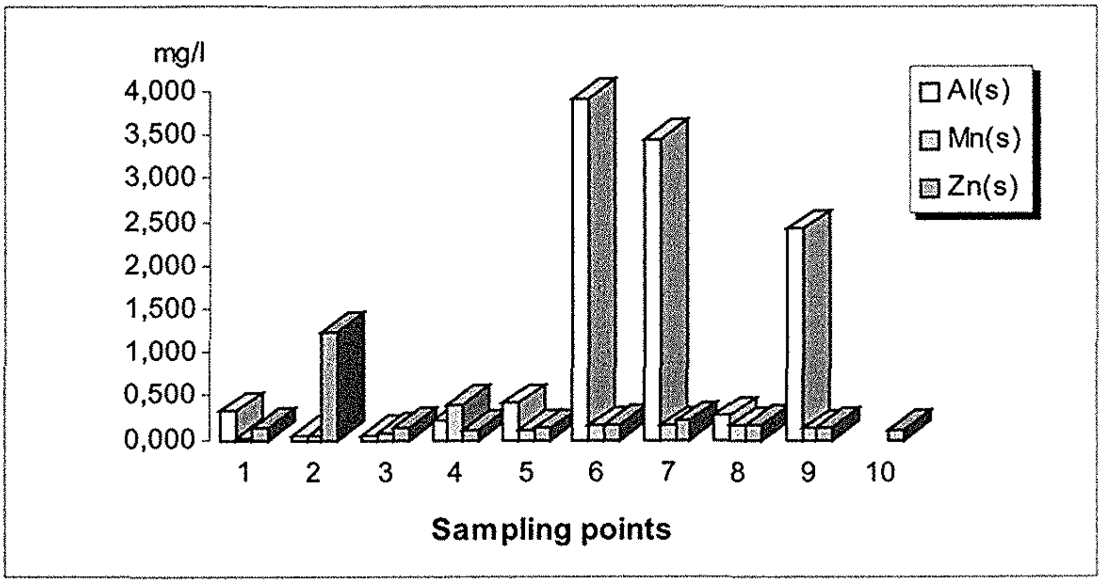

Figure 6. Al, Mn and Zn concentrations in water (summer).

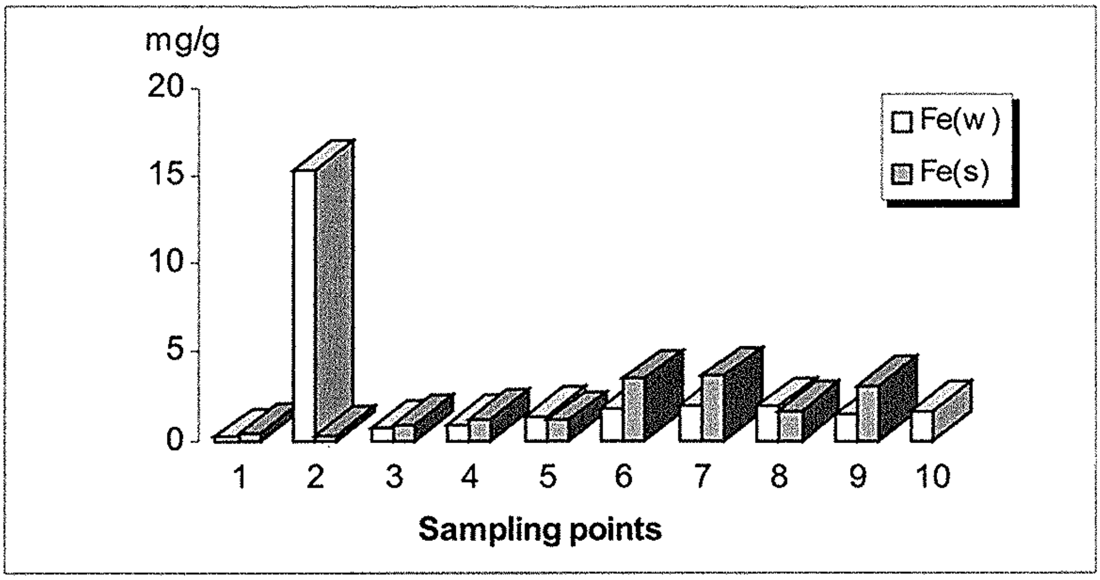

Figure 7. Fe concentrations in water, in winter (w) and summer (s)

High copper concentration in the Santa Tecla region (Figure 8) and at the last sampling points is caused by its use as fungicide. High concentration of copper was also found in the analyzed macrophyte, the *T. diuretica*.

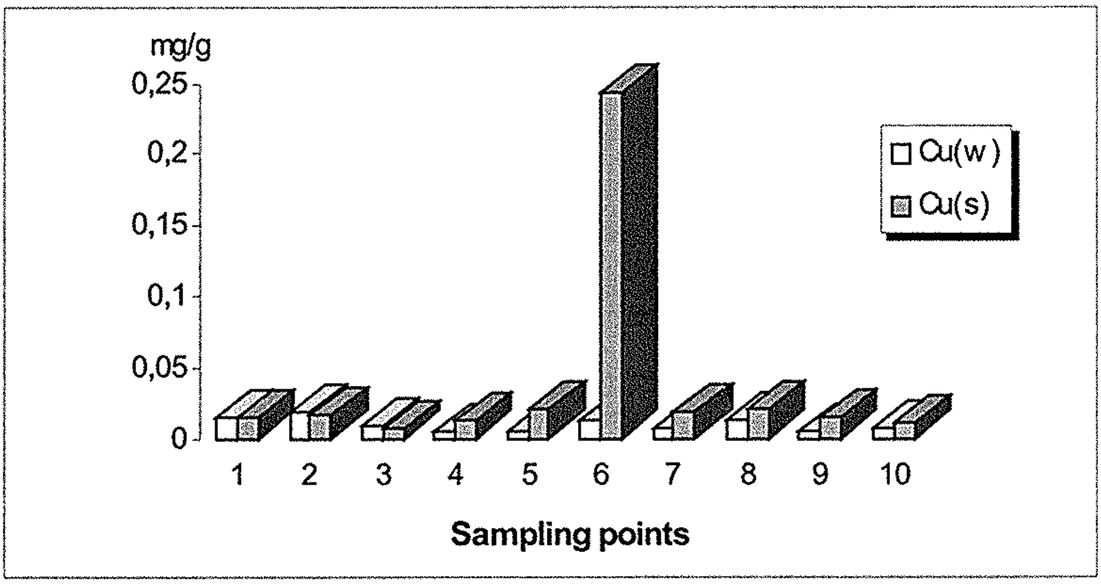

Figure 8. Cu concentrations in water, in winter (w) and summer (s)

During the cold season, an increase in the concentration of iron can be observed in the bathed area. This is probably due to the reduction of the activity of aerobic microorganisms. This leads to the accumulation of organic acids that function as ligands for the iron contained in the sediment and its mobilization for the hydric compartment, due to complexation processes.

Manganese in the hot season presents inverse behavior in relation to the cold season in the wetland area. In the hot season occurs a decrease and in the cold season occurs an increase of its concentration in water. Zinc, with lower concentrations, presents similar behavior to manganese. Copper presented very low concentrations in both seasons. Even so the copper concentrations are higher in the cold season, especially at point 6, near a waste treatment facility in city of Esteio.

A higher aluminium concentration can also be observed at points 6 and 7, probably due to leaching of clays that are the major component of the soils of this region. At point 1, which has higher declivity with regard to point 2, due to the Botucatu Formation[14] sandstone elevations, the concentrations of Al also indicate leaching processes. In the hot season, an increment in the concentrations of this element occurs in the water course.

Figures 9, 10 and 11 present the elements concentrations in the soluble sediments.

The effect of the erosive process on the sandstone and basalt rocks is illustrated by the higher concentrations of Al, Fe and Mn in the upper level reaches of Sapucaia Stream.

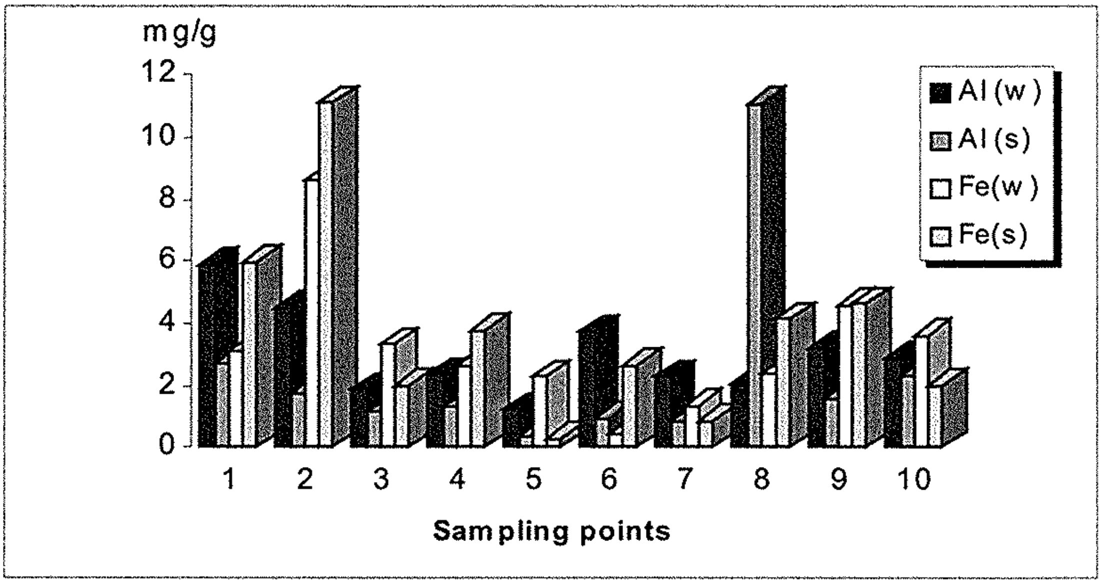

Figure 9. Al and Fe concentrations in sediment (soluble), in winter (w) and summer (s)

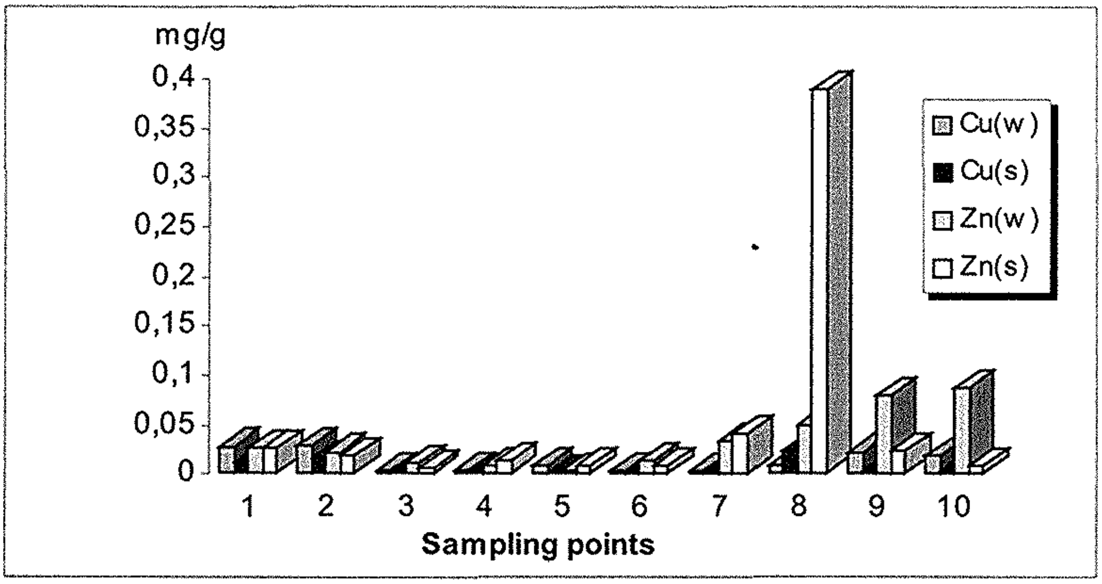

Figure 10. Cu and Zn concentrations in sediment (soluble), in winter (w) and summer (s)

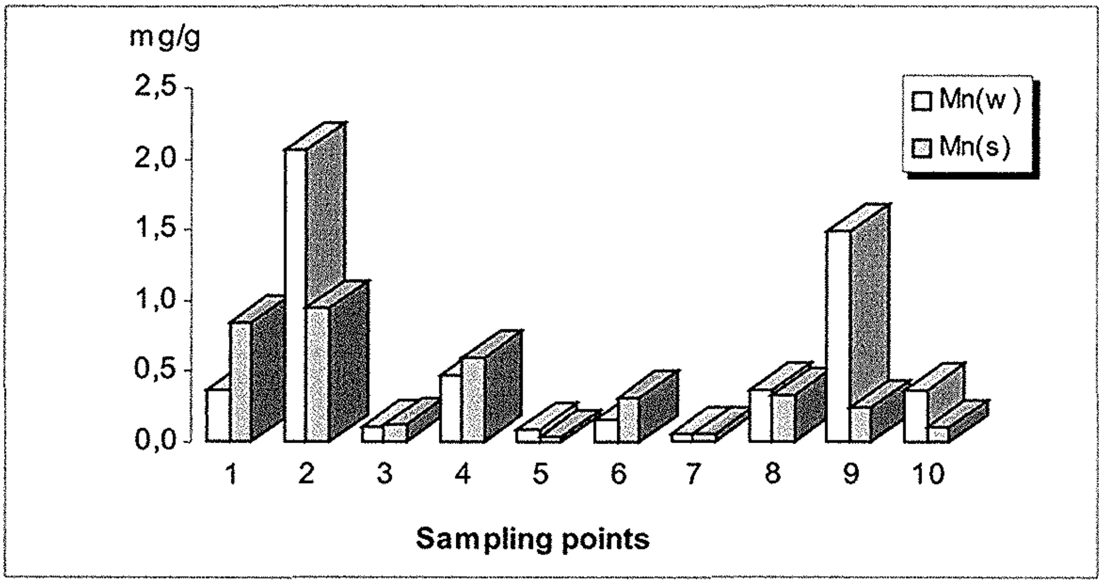

Figure11. Mn concentrations in sidiment (soluble), in winter (w) and summer (s)

It can be seen that the Al, Fe, Zn and Cu concentrations are higger in the final reaches due to the anthropic action.

Figures 12, 13 and 14 present the concentrations of the elements in the macrophytes.

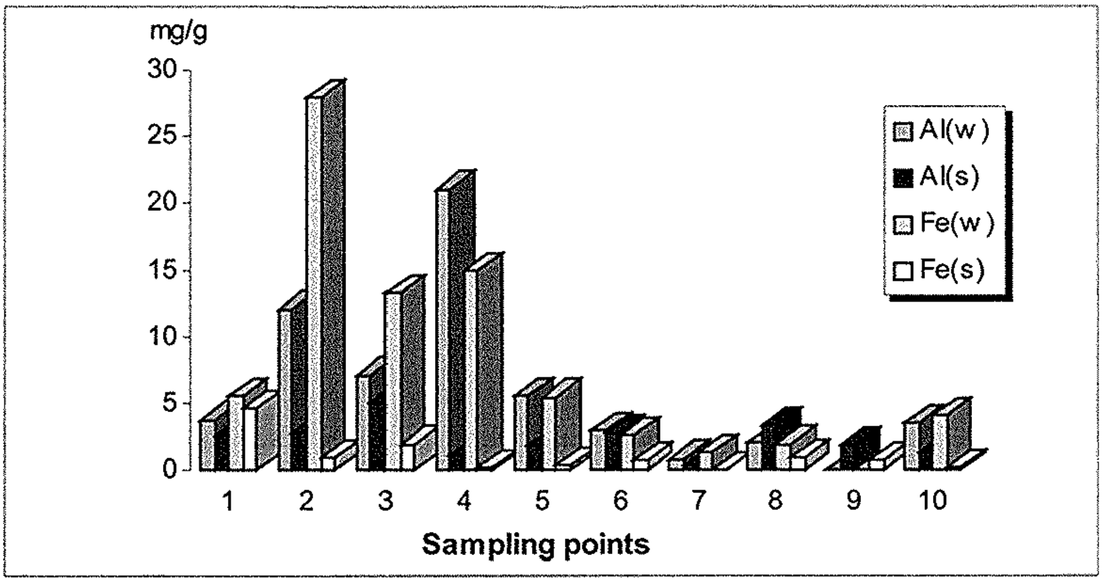

Figure 12. Al and Fe concentrations in macrophytes (mg/g)

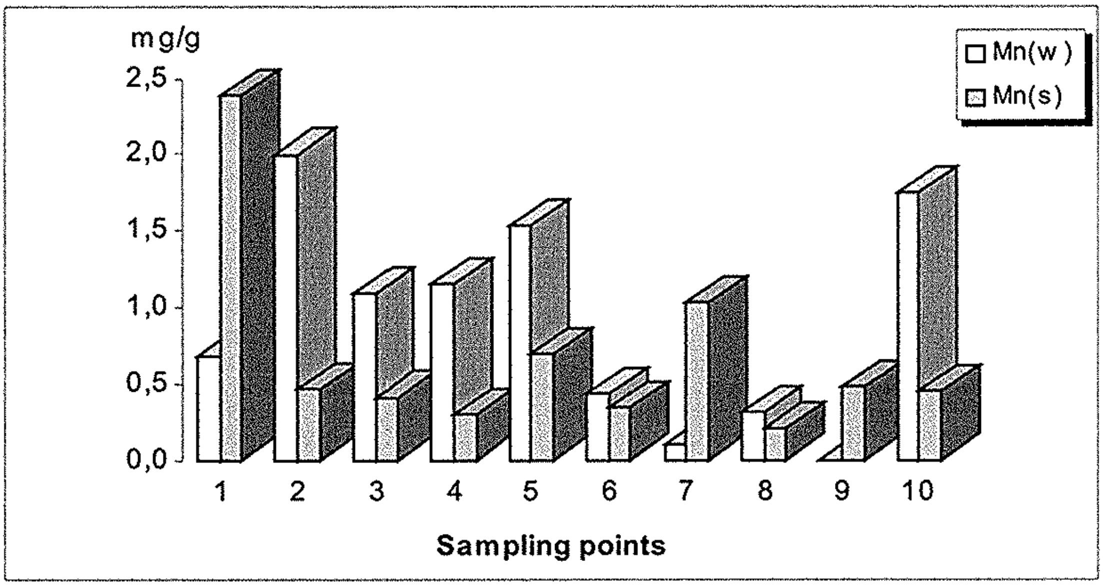

Figure 13. Mn concentrations in macrophytes (mg/g)

The macrophytes present higher Al, Fe and Mn concentrations in the upper reaches. This shows the correlation with the concentrations found in water and in sediments. Also the higher Zn and Cu concentrations in the final reaches show the correlation with the concentrations found in water and in the sediments.

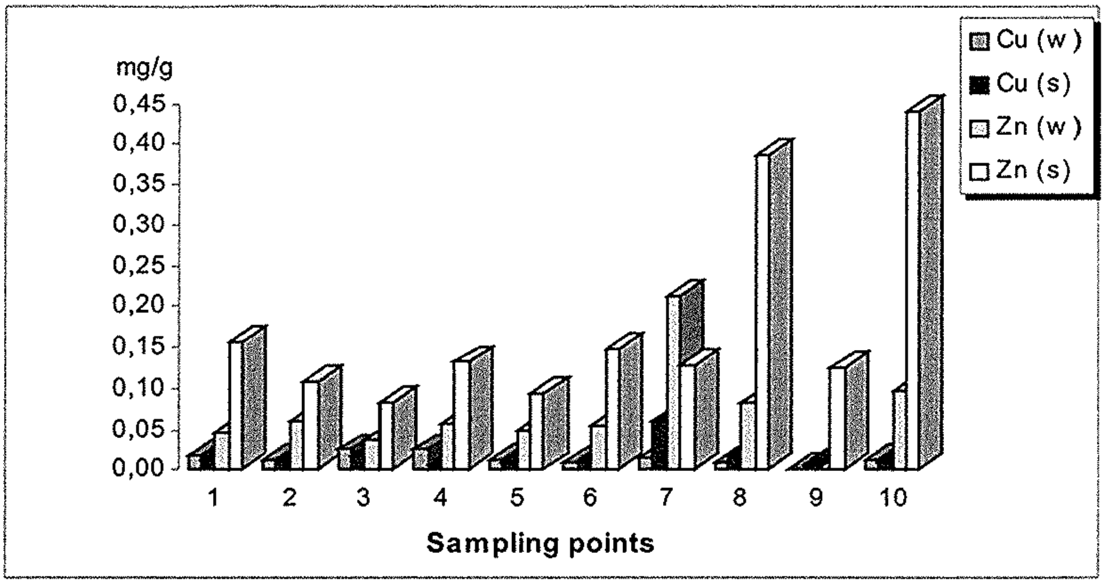

Figure 14. Cu and Zn concentrations in macrophytes (mg/g)

Figure 15 presents the elements concentrations found in fish (*R. quelen*).

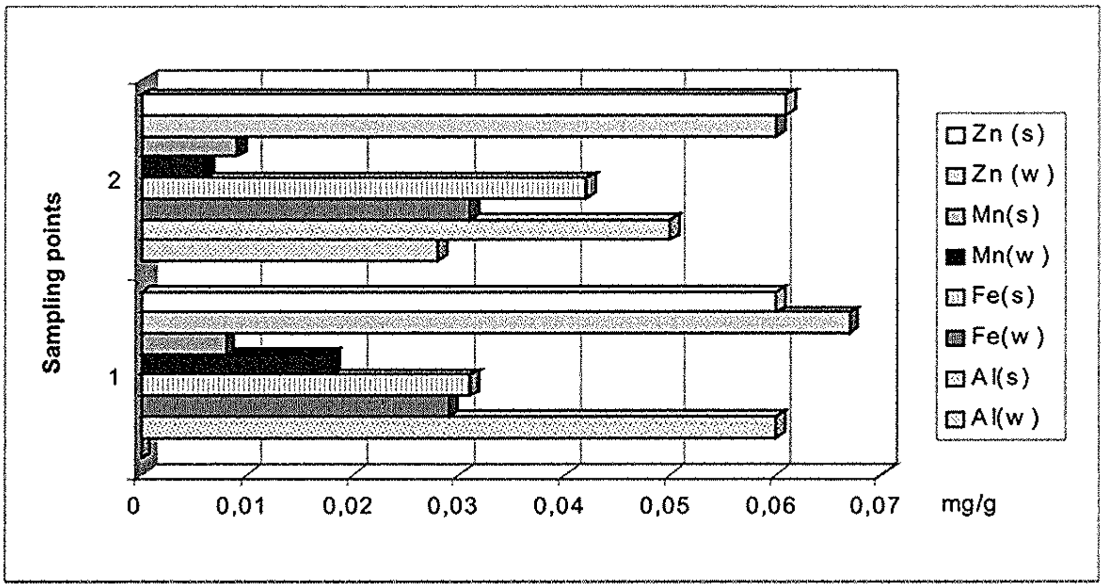

Figure 15. Al, Mn and Zn average concentrations (mg/g) in fish muscle down stream (2) and up stream (1), in winter (w) and summer (s)

It can be observed that, during winter, Zn and Mn have higher concentrations in the upper part of the stream. In the hot season, Fe has a higher concentration in the final reaches and Al in the upper area. Al was detected, by the methods used, only in the final reaches of the urban and industrial area.

The fish collected at sampling points 4 and 8 present no significant differences for lipids peroxidation in the liver. Significantly different average levels of lipids peroxidation were determinated at gills (1.485 nmol TBARS/mg protein, for sampling station 4 and 4.234 nmol TBARS/mg protein, for sampling station 8) and at muscles (0.574 nmol TBARS/mg protein, for sampling station 4 and 4.387 nmol TBARS/mg protein, for sampling station 8) of the collected animals.

CONCLUSIONS

This paper presents the results of the effects of the urban and industrial activities on water and sediment quality of the Sapucaia Stream. At its final course, the great alterations observed in the physico-chemical parameters of water interfere with the water quality of the Sinos River. This river belongs to Guaíba Hydrographic Basin.

At the final reach of the Sapucaia basin, a large increase of metal concentrations in the atmosphere is observed. A correlation was found among the concentrations of some elements in macrophytes, water and soil sediment.

High values for copper were found in the atmosphere and in the macrophyte *T. diuretica* at the upper course. This high concentration of copper may be due to its use in fungicides or mining activities of this region.

Alterations were observed on macrophytes and sediments with the increase of the environment pollution, at the final area of the basin. Significant differences were found for the lipids peroxidation at the gills and at the muscles of the collected fishes in the rural and in the industrial areas.

The water quality of the final area of Sapucaia stream presents alterations which may affect the life quality of the local population.

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