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TRACE METALS DISTRIBUTION IN SEDIMENT PROFILES FROM REMOTE LAKES IN THE PANTANAL SWAMP, CENTRAL BRAZIL

L.D. Lacerda

Departamento de Geoquímica, Universidade Federal Fluminense, Niterói, RJ

ABSTRACT

The concentrations of Cu, Zn, Pb and Hg and their distribution in sediment core were studied in two lakes in the Northern Pantanal swamp, Central Brazil.

Surface sediment concentrations showed to be very low when compared to background values of both tropical and temperate lakes. However, the enhancing anthropogenic impacts in the area have caused an increase in trace metal concentrations in relation to the local background. This enrichment can reach up to 4 times for Hg and from 2 to 3 times for Cu, Zn and Pb, in the last decade.

The results suggest that the atmosphere, in the case of Hg and probably of Pb, and run off from agricultural and urban soils, are the major source of trace metals to these lakes. After deposition, Pb mobility is probably influenced by iron hidroxides geochemistry while Hg, Cu and Zn are highly influenced by the organic matter in these lake sediments.

RESUMO

As concentrações de Cu, Zn, Pb e Hg, e sua distribuição em perfis de sedimento foram estudados em dois lagos no Norte do Pantanal Matogrossense.

As concentrações de metais nos sedimentos de superfície mostraram-se muito baixas quando comparadas aos valores de "background" de lagos tropicais e temperados. Entretanto, os impactos antrópicos sobre a área causam um aumento da concentração de metais em relação ao "background" local. Este aumento atingiu quatro vezes para Hg e de duas a três vezes para os demais metais.

Os resultados sugerem que a atmosfera, no caso do Hg e provavelmente do Pb, e a erosão de solos de agricultura e urbanos são as principais fontes de metais para estes lagos. Após a deposição, a mobilidade do Pb mostra-se influenciada pelo comportamento do ferro, enquanto Hg, Cu e Zn são muito influenciados pelo comportamento da matéria orgânica.

INTRODUCTION

The Pantanal swamp is a major wild life sanctuary in Central Brazil. The region is a holocenic sedimentary plain covering an area of about 400,000 km². In recent years, the traditional extensive ranch practices have been faced with increasing large scale agriculture, mining and industrial growth, which led to worring environmental impacts including deforestation, waterways sedimentation and increasing concentrations of pesticides, mercury and other anthropogenic substances (CETEM, 1989; Lacerda et al., 1991).

The Poconé municipality is located in the Northern portion of the Pantanal region, being the most potentially affected area by the present and future anthropogenic impacts. The area is presently under intense pressure of gold mining, large scale agriculture and accelerated population growth (CETEM, 1989). Trace metals are by-products of such activities and their inputs to the local environment are probably increasing. For example, atmospheric deposition rates of Hg originated in gold mining sites has increased by a factor of 4 in the last decade, and is presently similar to industrialized North European regions (Lacerda et al., 1991). Other trace metals like Pb, Cu and Zn may probably follow the same trend, although there is no data up to now regarding their local concentrations. Therefore, the knowledge of their present day concentrations in the Northern Pantanal region is urgently needed, in order to establish their background concentrations and to monitor their potential increase in future years.

The objective of the present work is to provide, for the first time, background concentrations of trace metals in the Pantanal swamp, and to identify possible increases in their concentrations through the study of sediment profiles in lakes of the region.

MATERIAL AND METHODS

This work was carried out in two lakes in the Poconé region, Mato Grosso State, central Brazil. The lakes were located around the Poconé municipality, where increasing anthropogenic activities are taking place for the last 20 years, including gold mining, mechanized

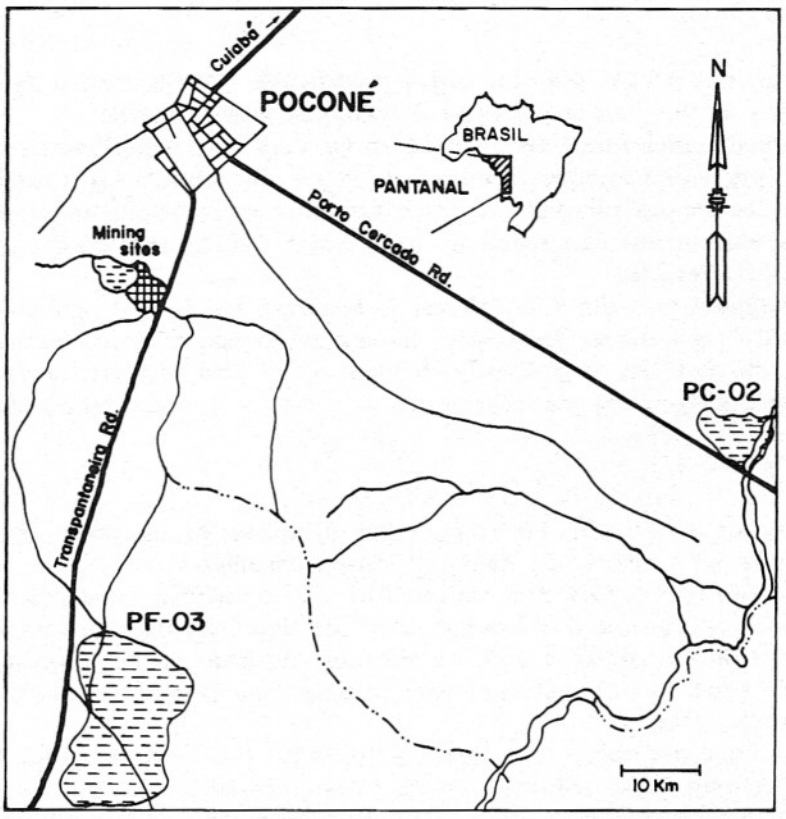

Figure 1 – Location of the studied lakes in the Poconé region, Mato Grosso State, Central Brazil.

agriculture, road construction and tourism. The studied lakes are located in remote areas and are permanently flooded, even during the dry period. They are large, shallow, open water lakes and with water depths ranging from 0.5 to 1.5 m. They are dominated by submersed macrophytes with emergent ones restricted to the shallow margins.

The studied lakes are located in the Pantanal Formation, a quaternary plain, constituted by sandy-clay sediments. The soils are hydromorphic laterites constituted by low activity clays and sands, associated with red-yellow podsols and euthrophic plansols (CETEM, 1989).

In each lake, 12 sediment profiles were collected using polyethylene cores (25 cm long) inserted by hand in the sediment. Each core was sliced in 1.0 cm layers in the first three centimeters; in 2,0 cm layers from three to seven centimeters depth; and in 3.0 cm layers therein. All layers of the same depth more pooled to form two composite samples for each lake. Samples were packed in plastic bags and frozen in the field for transport.

Sediment samples were oven dried (50°C) and wet digested in duplicate using the procedure of Malm et al. (1989). Heavy metals, with the exception of Hg, were determined through conventional flame atomic absorption spectrophotometry. Mercury was measured in sediment extracts by hydride generator atomic absorption spectrophotometry (Malm et al., 1989). Reproductiveness and precision of the methods are published elsewhere (De Paula, 1989). Aliquots were used for gravimetric determination of organic matter content after ashing at 450°C for 16 h.

RESULTS AND DISCUSSION

Surface sediment concentrations of Cu, Zn, Pb and Hg from Pantanal lakes are shown in Table 1, compared to other lakes from different parts of the world. Only background values from these lakes were considered to provide a significant comparison with such remote lakes. The relative abundance of the trace elements (Zn>Cu>Pb>Hg) is similar among the lakes and follows their relative abundance in the Earth crust, since they represent mostly background concentrations.

Table 1 – Concentrations of trace metals in various lake sediments compared with the surface sediment concentrations found in the Pantanal Lakes (background values only in ug.g^{-1} dry weight).

Site	Hg	Zn	Cu	Pb	Author
Pantanal	0.06-0.08	23-30	10-18	7-13	This study
Madeira River Basin	0.1 -0.5	101-223	12-27	24-43	Lacerda et al. (1990)
Lake Constance, Germany	-	111	24	19	Frevert & Sollman (1982)
Great Lakes, USA	-	7-120	16-44	14-40	Forstner & Wittman (1979)
Ontario Lake, Canada	<0.2	50	20	5	Johnson (1987)
Lake St. Clair, Canada	-	45	9.5	10.6	Rossman (1988)
Lake Kinneret, Israel	-	30-100	10-30	1-5	Frevert & Sollman (1982)
Fontana Lake, USA	2.0	181	46	-	Abernathy et al. (1984)

Trace metal concentrations in Pantanal lakes sediments are very low when compared to European and North American lakes, even when considering only the background concentrations of these lakes. For example, background values for US Great Lakes (Forstner & Wittman, 1979) and Lake St. Clair, Canada (Rossman, 1988), which are particularly low, are still nearly 2 to 3 times higher than the values found for surface sediments in the Pantanal lakes studied.

Very few data exist on the trace metal concentrations in remote tropical lakes. It seems from the data presented here that background values for tropical lakes, in particular of those located in quaternary plains are very low. Metal-poor geological formations and low anthropogenic inputs may explain the low concentrations found in Pantanal lakes when compared to background values of temperate, North American and European lakes.

Comparisons can be made with a few data from Africa and Amazonian lakes. Bugenyi (1986) reported Cu concentrations in surface sediments from Lakes George and Edward in Uganda, ranging between 30 and 125 ug.g^{-1}, which are also higher than the values reported here. In the Madeira River basin, Western Amazon, which received freshly eroded sediments from the Andes mountains, Lacerda et al. (1990) reported concentrations of Zn (101-223 ug.g^{-1}), Cu (12-27 ug.g^{-1}), Pb (24-43 ug.g^{-1}) and Hg (0.13-0.49 ug.g^{-1}), which are also higher than the Pantanal Lakes studied. These and other values presented in Table 1 strongly suggest that the Pantanal lakes are extremely poor in trace metals. Therefore, even small increases in their concentrations, may case a significant impact on the local biota.

The distribution of trace metal concentrations in sediment profiles of the studied lakes is shown in Figure 2. Notwithstanding the low concentrations measured, an increase in metal content in surface sediments, compared to deeper layers, can be clearly seen in the profiles, in particular in the case of Hg and Zn, with a 2 to 4 times growth and to a lesser extent of Pb and Cu.

Mercury has been reported as an important by-product of the local gold mining, where it is used to amalgamate fine gold particles present in the soil. Mercury deposition rates over the Poconé region has been estimated to reach 120 ug.m^{-2}.y^{-1} (Lacerda et al., 1991). Therefore, Hg increase in surface sediments is definitively of anthropogenic origin. Zinc and Cu are present in various pesticides used in the local agriculture and are ubiquitous elements in urban wastes (Nriagu & Rao, 1987). Lead is an important by-product of gasoline combustion. Therefore, the increase in these elements concentrations may also be due to the growing anthropogenic activities in the region.

Post deposition mobility of trace metals was investigated through correlationships with major metal-carriers; organic matter and iron contents of the sediment layers (Table 2). The studied

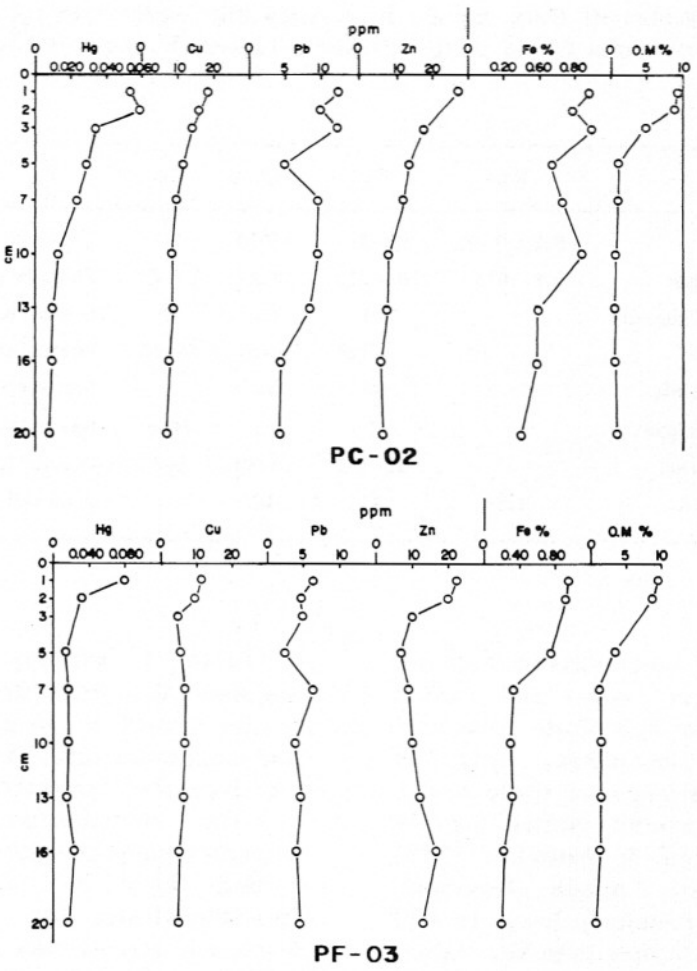

Figure 2 – Trace metals (ug.g^{-1}) and organic matter (%) concentrations in sediment cores from remote lakes in the Pantanal swamp, Poconé region, Mato Grosso State, Central Brazil.

Table 2 – Correlation coefficients between trace metal concentrations and Iron and organic matter contents in sediment profiles of remote lakes from Northern Pantanal, Central Brazil. (** P>0.01)

Lake PF-03				
	Zn	Cu	Hg	Pb
Iron	0.61	0.63	0.63	0.50
Organic matter	0.81**	0.88**	0.81**	0.59
Lake PC-02				
	Zn	Cu	Hg	Pb
Iron	0.60	0.64	0.60	0.87**
Organic matter	0.96**	0.97**	0.93**	0.69

metals behave differently. Lead presented a significant correlationship with iron but not with organic matter, while Cu, Zn and Hg did not correlate with iron, but showed strong significant correlationships with organic matter content of sediment layers. Previous studies in the Amazon region showed that Fe oxides are the major carriers of trace metals in rivers (Gibbs, 1973; Lacerda et al., 1990). Our results, however, showed that at least after deposition organic matter plays a major role in metal mobility in Pantanal lakes.

The results presented here, although preliminary, are probably the first to assess trace metal distribution in Pantanal lakes. However, since no comparative data seem to exist for the region, these results should be viewed with care, since a multitude of different lakes, with different geology and geochemistry, exist in the area, which may exibit completely different patterns of metal distribution.

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REFERENCES

ABERNATHY, A.R.; LARSON, G.L.; MATHEWS, R.C. (1984) Heavy metals in surficial sediments of Fontana Lake, North Carolina. Water Res., **18**: 351-354.

BUGENYI, P. (1986) Trace metal concentrations in Lakes George and Edward, Uganda, Environm. Poll., **16**: 22-29.

CETEM (1989) Desenvolvimento de Tecnologia Ambiental. Rel. Final, Centro de Tecnologia Mineral, CNPq, Rio de Janeiro.

DE PAULA, F.C. (1989) Geoquímica de sedimentos da bacia ocidental do Rio Madeira, Rondônia. Dissertação de mestrado, Universidade Federal Fluminense, Niterói, 71p.

FORSTNER, U. & WITTMAN, T.W. (1979) Metal pollution in the aquatic environment. Springer-Verlag, Heidelberg.

FREVERT, T. & SOLLMAN, C. (1982) Heavy metals in Lake Kinneret (Israel). III. Concentrations of iron, manganese, nickel, cobalt, molybdenium, zinc, cadmium, lead and copper in interstitial water and sediment dry weights. Arch. Hydrobiol., **109**: 181-205.

GIBBS, R.J. (1973) Mechanisms of metal transport in rivers. Science, **180**: 274-280.

LACERDA, L.D.; DE PAULA, F.C.; OVALLE, A.R.C.; PFEIFFER, W.C.; MALM, O. (1990) Trace metals in fluvial sediments of the Madeira River watershed, Amazon, Brazil. Sci. Tot. Environm., **97/98**: 525-530.

LACERDA, L.D.; SALOMONS, W.; PFEIFFER, W.C.; BASTOS, W.R. (1991) Mercury distribution in sediment profiles from lakes of the high Pantanal, Mato Grosso State, Brazil. Biogeochemistry, **14**: 91-97.

MALM, O.; PFEIFFER, W.C.; BASTOS, W.R.; SOUZA, C.M.M. (1989) Utilização do acessório de geração de vapor frio para análise de mercúrio em investigações ambientais por espectrofotometria de absorção atômica. Ciênc. Cult., **41**: 88-92.

NRIAGU, J.O. & RAO, S.S. (1987) Response of lake sediments to changes in trace metal emissions from the smelters at Subdury, Ontario. Environm. Pollut., **44**: 211-218.

PFEIFFER, W.C.; LACERDA, L.D.; MALM, O.; SOUZA, C.M.M.; SILVEIRA, E.G.; BASTOS, W.R. (1989) Mercury concentrations in inland waters of gold mining areas in Rondônia, Brazil. Sci. Tot. Environm., **87/88**: 233-240.

ROSSMAN, R. (1988) Estimation of trace metals storage in lake St. Clair post-settlement sediments using composite samples. J. Great Lakes Res., **14**: 66-75.