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# Mercury distribution in sediment profiles from lakes of the high pantanal, Mato Grosso State, Brazil

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**Abstract**. Sediment cores from lakes located in the Pantanal Swamp, Central Brazil were analysed for the distribution of mercury released by the local gold mining. Atmospheric transport is the only pathway of mercury contamination of these remote lakes. Mercury concentrations were higher at the surface of sediments (62 to 80 ug.kg$^{-1}$) decreasing to values of 20 to 30 ug.kg$^{-1}$ in deeper layers. Mercury deposition rate was estimated as 90 to 120 ug Hg.m$^{-2}$.yr$^{-1}$. Although mercury concentrations were much lower than in industrialized areas, mercury deposition rate for these Pantanal lakes is of the same order of magnitude of deposition rates measured in lakes in industrialized areas.

## Introduction

Sediments are important carriers for trace metals in the environment and reflect the current quality of the system. Analysis of the development of concentrations of metals along sediment cores therefore makes it possible to determine the history of metal contamination for a certain region. The metals can derive from direct discharges or from diffuse pollutant sources like atmospheric deposition.

In a study of an Adirondack lake (Scrudato et al. 1987) it was possible to attribute increases of mercury at greater depth in lake cores to lumbering and related activities. However, most lake sediments show higher mercury concentrations (and other metals) in the surface layers compared with the deeper layers (Aston et al. 1973; Cowgill 1975; Madsen 1981; Simola & Lodenius 1982; Bjornklund 1984; Rekolainen et al. 1986; Evans 1986). Most of mercury increases in lake sediments from industrialized areas can be explained by direct industrial discharges through the atmosphere.

In Brazil mercury is currently extensively used as a reagent to concentrate gold from gold bearing soils and sediments. The burning of the amalgam formed causes high mercury inputs into the atmosphere. The evaporated mercury is returned to land surfaces and waters with wet and dry deposition and accumulates in soils and sediments (Pfeiffer & Lacerda 1988; Lacerda et al. 1989; Marins et al. 1990). Sediment cores therefore may provide an excellent way to determine the history of mercury contamination in gold mining areas.

The Pantanal swamp is a major wildlife sanctuary in Brazil. In recent years however, the increasing gold mining activity along its northern border has worried local environmental authorities due to possible contamination of the Pantanal with Hg used in the process of gold amalgamation and extraction. Recent estimates showed that from 10 to 20 tonnes of Hg has been released in the area by this process. Although major mining sites are located outside of the Pantanal itself, Hg could reach the area either through leaching of Hg contaminated tailings or through atmospheric transport and deposition (Lacerda et al. 1991; Marins et al. 1991). However, previous work done in the area showed that Hg has a very low mobility in tailings and very little if any at all reach the Pantanal swamps through local drainages (Lacerda et al. 1991). On the other hand extremely high Hg concentrations in the atmosphere, up to 1.7 $ng.1^{-1}$ of air, have been measured over areas of ore roasting and purification (Marins et al. 1991). Therefore the atmospheric pathway should more likely be the source of contamination of the Pantanal swamps.

In the present paper we investigate the possible Hg atmospheric transport to the Pantanal swamps, through the analysis of sediment profiles of remote lakes located at different sites in relation to potential sources of atmospheric Hg in the Pocone district, Mato Grosso State, Brazil.

## Material and methods

The study was done in two lakes in the Pocone region, Mato Grosso State, central Brazil. The lakes were located around the Pocone municipality where most of gold mining and ore processing take place. The lakes are located in remote areas and are permanently flooded, even during the dry period. They are large open water areas dominated by submersed macrophytes with emergents restricted to the shallow margins.

In each lake 12 sediment profiles were collected using polyethylene cores (25 cm long) inserted by hand in sediments. 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 were pooled to form two composite samples for each lake.

Samples were packed in plastic bags and frozen in the field for transport. Lake water temperature, pH, Eh and conductivity were measured in triplicate using portable electrodes. Subsamples (500 ml) were collected in duplicate and filtered through 0.45 u Millipore filters for the gravimetric determination of total suspended solids (TSS).

Sediment samples were oven dried (50 °C) and wet digested in duplicate using the procedure of Malm et al. (1989). Mercury was measured in sediment extracts by hydride generator atomic absorption spectrophotometry. Detection limit of the method used was 0.04 ug.$l^{-1}$. Reproducibility and precision of the method are published elsewhere (Pfeiffer et al. 1989; Malm et al. 1989).

Aliquots were used for gravimetric determination of organic matter content after ashing at 450 °C for 16 h.

## Results and discussion

The physiographic characteristics of lakes and their major water physico-chemical parameters are presented in *Table 1.* The lakes are shallow (50 to 120 cm), have a low content of suspended solids (13.0 to 16.8 mg.$l^{-1}$), a moderate redox potential (136 to 196 mV), a low conductivity (14 to 48 uS.$cm^{-1}$), and are slightly acidic pH (5.7 to 6.4). These data suggest restricted sediment remobilization and that the mercury from atmospheric deposition will be incorporated in the sediments (Rekolainen et al. 1986). Macrophytes roots were scarce and composed of small nutritive roots restricted to the first 5 cm of the sediment profile.

The distribution of organic matter and Hg concentrations along sediment profiles of the two lakes are presented in Fig. 1. Organic matter content decreased from maximum values at the sediment surface (ca 10%), to very low values (1%) at deeper layers. The organic matter profiles indicate that these sediments are not subject to remobilization and that optimal conditions for Hg retention in surface sediments occur.

*Table 1.* Major physico-chemical parameters of lake water in the Pantanal swamps, Mato Grosso State, Brazil.

| Lake n° | Conductivity (uS.$cm^{-1}$) | pH | *T* (°C) | Eh (mV) | TSS (mg.$l^{-1}$) | Depth (cm) |
|---|---|---|---|---|---|---|
| PC-02 | 14 | 5.7 | 29 | 196 | 13.0 | 60—80 |
| PF-03 | 48 | 6.4 | 28 | 136 | 16.8 | 50—120 |

Mercury concentrations were higher in surface sediments of lakes ranging from 62 to 80 ug.kg$^{-1}$, decreasing steadily therein to nearly constant values between 12 to 30 ug.kg1$^{-1}$ (Fig. 1), which are similar to background values reported for the area (Lacerda et al. 1991). In these two lakes peaks of organic matter content and Hg concentration presented the same distribution throughout the profile, although elevated Hg concentrations were restricted to the first 2.0 cm of the core.

The mercury concentrations found are very low when compared to remote lake sediments from the northern hemisphere. Evans (1986)

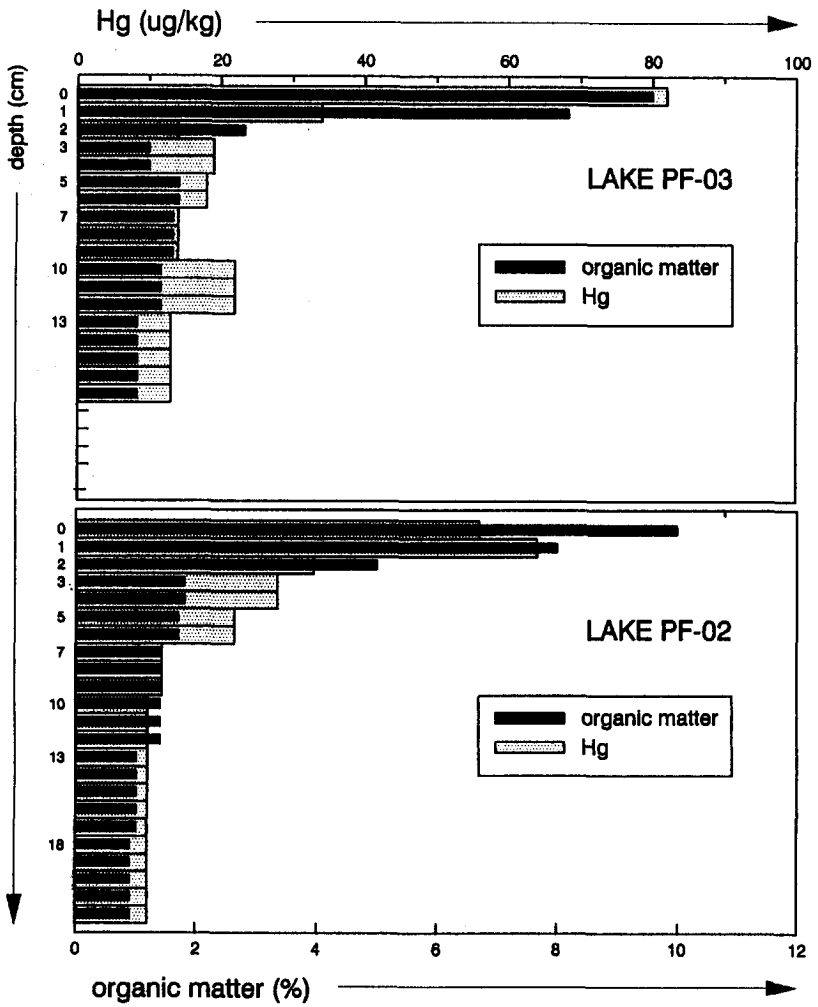


*Fig. 1.* Mercury (ug.kg$^{-1}$) and organic matter (%) concentrations in sediment cores from remote lakes in the Pantanal swamps, Mato Grosso State Central Brazil.

reported background values for remote Canadian lakes to be ca 100 $ug.kg^{-1}$, while surface sediments presented values up to 560 $ug.kg^{-1}$. Andren & Nriagu (1979) considered background values for northern hemisphere lakes of ca 330 $ug.kg^{-1}$. Rekolainen et al. (1986) found background Hg concentration in remote lakes of Finland to range between 50 to 250 $ug.kg^{-1}$ but found values as high as 550 $ug.kg^{-1}$in the surface layers of these lakes. These data are considerably higher than the concentrations found in the present study and are due to the presence of Hg rich base rocks in most Canadian and North European areas and reflect antropogenic Hg emissions in these areas.

As gold mining activities, and therefore Hg emissions to the atmosphere, started in the area in 1981, we can use Hg distribution throughout the sediment profiles to estimate sedimentation rates and mercury accumulation for the region. Assuming Hg background concentrations to be between 10 to 30 ppb, the data of profiles PC-02 and PF-03 showed a steady increase in Hg concentration from around 2.0 cm of depth. Therefore we can estimate a sedimentation rate of 0.22 cm per year. Using the Hg concentrations found in the top 2 cm (60 to 80 $ug.kg^{-1}$) we can estimate a mercury accumulation rate ranging from 90 to 120 ug $Hg.m^{-2}$ per year.

Assuming an area of circa 100 $km^{-2}$ under the influence of local gold mining, which is the larger distance were Hg concentrations are still slightly higher than background values and a total Hg emission of 10 to 20 tonnes (Lacerda et al. 1991), an estimated Hg concentration in the surface soils and sediments would be around 200 to 300 $ug.m^{-2}$. Therefore our present estimate is in the same order of magnitude and thus remarkably in accordance with Hg emissions to the local atmosphere during the last 10 years.

Table 2 compares Hg deposition rates estimated for the Pocone lakes and other deposition rates published in literature. Although mercury

*Table 2.* Mercury in sediment profiles from various lakes and calculated deposition rates.

| Location | Background concentration ($ug.kg^{-1}$) | Surface sediments ($ug.kg^{-1}$) | Deposition rates ($ug.m^{-2}.yr^{-1}$) | Author |
|---|---|---|---|---|
| Pocone | 15—25 | 60—80 | 120 | This study |
| Finland, remote | 20—50 | 20—50 | 25—50 | Rekolainen et al. (1986) |
| Finland, contaminated | 50—250 | 170—550 | 370 | Rekolainen et al. (1986) |
| Denmark | 151—523 | 243—314 | 30—200 | Madsen (1981) |
| Finland | 250 | 430 | 120 | Simola & Lodenius (1983) |

concentrations in surface and deep sediments of Pocone lakes are lower than those values reported for industrialized areas, deposition rate is very similar to such areas suggesting the importance of Hg contribution from gold mining to the Pantanal area, even considering that the remote lakes studied are relatively far from direct effluents from gold mining.

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