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Total-Hg and ^{210}Pb measurements in canopy and lake sediments at the pic Matecho, a pristine site in the tropical rainforest of French Guiana (South America)

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Abstract. We present results obtained from a pristine site of French Guiana (South America), at the Pic Matecho, a region far from gold mining activity. This area contains a small permanent lake, a rare situation in French Guiana. Tree canopy, soils and Lake Matecho sediments were analysed in total Hg and ^{210}Pb. The annual deposit of litterfall is estimated at 40 µg (Hg)/m^2/y. The top sediment content of 0.2 µg (Hg)/g indicates a large contribution of the atmospheric deposit. In sediment, the decrease of total Hg with depth is neither due to local human influence, nor to increase of atmospheric background during this century. It is attributed to remineralization of organic matter in the upper part of the sediment : the majority of the total Hg deposited at the water/sediment interface is not permanently trapped in the sediment but remobilized in water. Interpretation of the historical sediment profile suggests a constant deposit rate over the last millennium.

1. INTRODUCTION

As in the Amazonian basin of Brazil, large areas of French Guiana (South America) have been exposed to gold mining since the 19th century. This activity uses large quantities of mercury (Hg) (1 to 4 kg Hg per kg of gold produced), which is mainly lost in the soil, river, sediments and the atmosphere. To estimate, understand, and finally prevent the resultant Hg pollution, studying the Hg cycle has been a major goal of the last twenty years (see e.g., Schroeder W, 1998). To estimate the anthropogenic impact we must first evaluate the background content and cycle in pristine areas never submitted to local/regional human influence. In these areas sedimentary deposits are essential to establish the chronological frame that gives access to fluxes. However, lakes are almost non existent in French Guiana, where intense and continual erosion processes preclude lake formation. We present here measurements made in 2001relating to sediment and canopy at a recently discovered remote lake, the lake of Pic Matecho .

2. SITE DESCRIPTION

The Pic Matecho lake is situated in the centre of French Guiana (03° 43' 44.5" N, 53° 02' 18.4" W), 3 km south of Pic Matecho (590 m asl), at an altitude close to 250 m. This appears to be an ideal pristine site : no gold mining ever existed in this area, and there has been no human settlement, at least during the last centuries. It is 150 km south of the Atlantic coast, 30 km northeast of the small village of Saül (ca. 200 inhabitants).

The site is under regular trade wind influence throughout the year with a prevailing northeast direction. This atmospheric circulation involves the first thousand meters of the atmosphere (the low troposphere), an air layer which carries most of the atmospheric load. This load in terms of gaseous

compounds and aerosol is therefore of Atlantic origin and is representative of background levels. This has been tested at the site of Petit Saut in French Guiana through a continuous monitoring of the aerosol load using the radionuclide ^{210}Pb, a major tracer of aerosol transport and deposit : the ^{210}Pb air concentration at Petit Saut is close to 0.2 Bq m^{-3} during both wet and dry seasons [1], a typical value of an oceanic air mass in tropical regions, similar to other studies [2, 3]. The air masses come directly from the Atlantic and do not cross gold mining areas; this trajectory precludes also any strong influence from the vast surrounding Amazonian regions where gold mining could load the atmosphere with Hg vapor. This site can therefore be considered to be under the influence only of the global background atmospheric load.

This small permanent lake (200 m long/50m wide/5m depth at centre), was recently discovered. The catchment area, situated at the foothill of the Pic Matecho is small: the origin of the lake sediments is both from atmospheric deposit and from the immediate surroundings (no influence from a large hydrologic complex, a situation rarely found in French Guiana where surfaces are very eroded and flattened).

3. MEASUREMENTS AND RESULTS

3.1 Sediments

The lake is highly stratified with a very low sedimentation rate. Coring was performed by diving. All sediment cores exhibit two distinct sections : an upper part rich in organic matter with low density, and a more compact lower section. The results presented here refer to a core of 20 cm length. Sediments were dried at 60°, a procedure that does not appear to affect the total Hg content in sediments. Lead 210 content was measured using γ spectrometry. The low density of the upper part of the sediment precluded any alpha spectrometry measurement and required the samples to be grouped by 3. Lead 210, a natural radionuclide (22.3 y) continuously produced in atmosphere, permits sediment dating over the last century.

The regular decrease of the ^{210}Pb depth-profile shows that, despite the very low density of the upper part of sediment, and despite the risk of sediment perturbation by falling trees, the deposit was regular over the last century (0.0046±0.0005g/cm^2/y). This indicates that the first 13 cm of the sediment were deposited during the century. Owing to sediment compaction and loss of organic matter, the lower part of the core is estimated to cover the last millennium.

The annual flux deposit of ^{210}Pb (obtained from the integrated deposition) at the water/sediment interface in centre of the lake is 180±30 Bq/cm^2/y, which is of the same order as the direct atmospheric deposit estimated in this region [1] and corresponds to estimations from ^{210}Pb profiles in surrounding soils : this indicates that the lake acts as a direct atmospheric collector.

The concentration of total Hg was measured using the cold vapour technique with atomic absorption spectrometry detection (Ama 254 of Spectra France). The total Hg concentration depth profile is similar to the profile of organic carbon percentage: it is constant in the first 10cm (200±20 ng/g and 30%) and then decreases to 55 ng/g and 6%, with both staying constant in the last 7 cm (figure 1). The correlation between total Hg, c(Hg), and % of organic carbon, C, is very strong (R^2 = 0.945) and the total Hg concentration can be approximated throughout the profile by the linear relation

$$c(Hg) = 4.3 \times (\% C) + 50 \qquad (1)$$

This indicates that the loss of Hg is related only to early diagenesis in the sediment : Hg deposited at the surface of the sediment under particulate form is continuously released into the water when organic matter is oxidized. This indicates also that Hg arrives in the sediment mainly bound to organic matter and is then released in soluble form (MMHg, Hg^{o}, Hg^{+2}?). This process ends at the depth of 12 cm and then Hg is definitively buried in the sediment. The flux of burying is 2.5 $\mu g/m^2/y$. revealing that 75% of the Hg deposited in sediment is remobilized in the water, making sediment as a strong source of available Hg in the hydrological cycle.

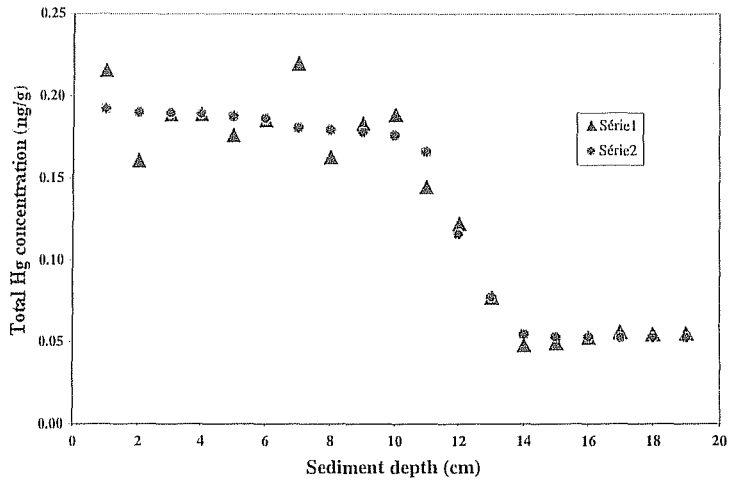

Figure 1. Sediment depth profile of the Total-Hg concentration (ng/g) measured (series 1) and reconstructed using relation (1) (series 2) from the organic carbon content in sediment. at Lake Matecho, a pristine site in the French Guiana tropical rain forest.

3.2 Historical reconstruction over the past millennium

The homogeneous composition of the core below 13 cm depth suggests a constant sedimentary process over the last millennium. In that part the constant concentration of total-Hg suggests a constant deposition flux. As the complete depth profile of the total-Hg can be reconstructed from the organic carbon content only (figure 1), we conclude that the sedimentary archive does not reveal any historical trend.

3.3 Canopy

The upper canopy (mature leaves) of 5 different species of trees were sampled. Trees were 30-35 m high, growing on drained soil. The forest of this region is well known for its high biodiversity. The collected species were *Chrisobalanaceae, Eperua falcata, Liane, Pourouma sp.* and *Caraipa sp. (Clusiaceae.* These belong to families representative of the tropical rain forest. Total Hg ranges from 52.4 ng g^{-1} to 103.0 ng/g.

The mean value obtained (69. 7 ng g^{-1} with σ = 16) does not significantly differ from the mean value over 5 species that we obtained at the Observatory of Les Nouragues (58.7 ng g^{-1} with σ = 28), a remote site in French Guiana [4].

Total Hg concentration in leaves has been measured by Roulet [5] in different parts of Brazil (along the Tapajos Basin and in the Tocantins Basin) and at three sites in French Guiana (c.a. 80 km south of

Cayenne), and results showed a higher content (mean value of 142 ± 50 ng g^{-1}) at the French Guiana site than in Brazil (mean value of 73± 40 ng g^{-1}). Our results indicate a lower value (55% less) for the remote areas of French Guiana. Few measurements exist in Europe in remote areas. Iverfeld [6] measured the pine needle concentration in remote areas of Sweden and found systematically lower values (40 ng g^{-1}). Other measurements in spruce needles performed in Scandinavia show similar values in the range of 40-50 ng g^{-1}. In tropical rain forest in different parts of the world the litter deposit on soil has been estimated. The annual deposit is of the order of 7 tons of dry matter per hectare [7, 8], which leads to an annual mean deposit on soil of 50 ± 10 µg Hg m^{-2} due to litterfall at the present site.

. As translocation (i.e., transfer of Hg from soil to leaves through the roots of the tree) is believed to be negligible (see for example [9, 10]), and as atmospheric load from soil emission is much smaller than the global atmospheric load in unpolluted areas as suggested in the literature, mercury in the canopy originates mainly from atmospheric uptake by the leaves. This measured flux, therefore, represents a direct atmospheric input into soils. In fact, it is the lower limit of the atmospheric deposit, as deposition due to throughfall must also be included in a forested area.

CONCLUSION

Results from a small isolated lake in French Guiana indicate that atmospheric transfer to the tree canopy is an important source of mercury for the soil of the tropical rainforest. The concentration in the sediment appears to be high for such a pristine region. The great majority of the total Hg deposited at the water-sediment interface is not permanently trapped in the sediment but is remobilized in the water. Interpretation of the historical sediment profile suggests a constant deposit rate over the last millennium.

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