

# Post-depositional processes in lake sediments traced by heavy metals and radionuclides: a case study from Lake Sirio (Ivrea, Northern Italy)

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**Abstract:** Heavy metal and radionuclide content and distribution with depth were analysed in sediment cores taken at different locations in a small peri-alpine lake. Data comparison suggests post-depositional remobilisation and concentration processes in the deepest part of the lake floor.

**Key words:** heavy metals, <sup>137</sup>Cs, <sup>210</sup>Pb, sedimentation rate, remobilisation

## INTRODUCTION

A detailed study on both the water and sediments of Lake Sirio (Ivrea, Northern Italy) has been conducted in recent years to evaluate its global “health” conditions (SACCHI ET AL., 2001; SACCHI ET AL., 2002; PERRONE AND FACCHINELLI, 2004). Within this framework, reliable sedimentation rates are crucial to interpret environmental data. These are normally derived from isotopic radio-chronometers, which allow the dating of sediment cores. Unfortunately, different phenomena including downward migration and remobilisation may affect their distribution profile with depth. Consequently, only the combined use of different isotope techniques and comparison with the distribution of other elements in the cores can help in reconstructing a sound chronology of events. Lake Sirio

is a small peri-alpine lake located close to Ivrea, in the Piemonte region (Northern Italy). The lake covers a surface of 0.3 km<sup>2</sup> with a drainage basin of 2.6 km<sup>2</sup>. Its maximum depth reaches 46 m. The lake has no tributaries and an artificial outflow only activated during precipitation events. The substratum is constituted by crystalline rocks and carbonates are absent in the drainage basin. The lake was originated mainly by glacial erosion during the Quaternary, although the morphology of the lake bottom suggests a combined tectonic origin.

Several lake sediment cores, ranging in length from 95 to 170 cm, were sampled at different locations and in different seasons. Cores were frozen, sliced into intervals, oven- or freeze-dried, and the loss of water calculated. Additional investigated param-

eters include mineralogy (XRD and SEM analyses) and organic matter content. Heavy metals' concentration (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn) was obtained on all samples by ICP-AES, after *aqua regia* digestion at the University of Torino. Core dating was performed on one core using different radioisotopes:  $^{14}\text{C}$  was analysed on the organic matter fraction by AMS at the Australian Nuclear Science and Technology Organisation;  $^{137}\text{Cs}$  and  $^{210}\text{Pb}$  were analysed at ARPA, Dipartimento sub-provinciale di Ivrea, by g-spectrometry.

## RESULTS

Distribution profiles of heavy metals in the sediment cores show distinctive patterns. Cores sampled at the maximum depth on the lake floor (46 m) show high mean contents and enrichment in the upper 70-90 cm for all metals except Fe and Mn. Other cores, taken at shallower depths (20 m), do not show a top enriched layer except for Cu and Zn. The comparison of heavy metals content below the top enriched layer, and the mean content of dioritic rocks, constituting the host formation of the lake, confirms that these represent "background concentrations" of lithogenic origin.

An enriched top layer is often observed in lake sediments and generally attributed to an anthropic input. In our case, the lack of industrial activities around the lake suggests an increased input by atmospheric wet deposition or by enhanced chemical weathering of the host rocks by acidic rain (STUMM AND BACCINI, 1978).

The distribution profile of  $^{137}\text{Cs}$  clearly shows a major peak around 9 cm below the sediment water interface, and a minor peak at 25 cm. The distribution profile is very similar to those obtained in other alpine lakes (KAMINSKI ET AL., 1994a; b). We attributed the major peak to the Chernobyl accident (1986) and the secondary peak to the year of maximum intensity of nuclear weapon tests in the atmosphere (1963).  $^{137}\text{Cs}$  deposition on Lake Sirio was calculated using activity distribution in the core. This leads to an estimate of  $11,000 \text{ Bq}\cdot\text{m}^2$ , a value which is about one third of the deposition measured in soils from the Ivrea region, summing up to  $30,000 \text{ Bq}\cdot\text{m}^2$  (FACCHINELLI ET AL., 2002). This discrepancy can only be explained by some type of removal of  $^{137}\text{Cs}$  following the Chernobyl fallout. Desorption from the sediments has been recognized especially in anoxic environments, because the  $\text{NH}_4^+$  strongly competes with caesium for the adsorption sites on clays (KAMINSKI ET AL., 1994b). In this case, a desorption of 7-8 % per year from the sediment could account for the missing  $^{137}\text{Cs}$ .

## DISCUSSION AND CONCLUSION

While the sedimentation rates calculated with  $^{137}\text{Cs}$  and  $^{210}\text{Pb}$  substantially agree (7-7.5  $\text{mm}\cdot\text{a}^{-1}$  for the upper portion of the core), the estimate based on radiocarbon greatly differs (mean sedimentation rate over the last 2000 years =  $0.5 \text{ mm}\cdot\text{a}^{-1}$ ). We previously interpreted this disagreement as an evidence of a dramatic increase in sedimentation rate during the last 50 years (SACCHI ET AL., 2001), due to eutrophication. In light of the heavy metals distribution profiles, a remobilisation from the shallower portions

of the lake bottom seems to have occurred. The organic matter content of all cores is similar. On the other hand, Fe and Mn concentrations are 3-10 times higher in the deepest cores. These two metals are known for their post-depositional mobility following seasonal redox cycles at the sediment-water interface (DAVISON, 1993). We suggest that Fe and Mn, associated with other elements, dissolve in water and later re-precipitate in

the deepest part of the lake floor, acting as a sink for many constituents. Arguments supporting this interpretation could be the distribution profiles of  $^{137}\text{Cs}$ ,  $^{210}\text{Pb}$  and heavy metals, which display similar, two-peaked patterns, and a seasonal increased metal concentration in the water column at 20 m depth. Further investigation is needed, to better define the phases and mechanisms involved in the dissolution-precipitation process.

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