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Heavy metals in Lake Balaton: water column, suspended matter, sediment and biota

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Abstract

During the period 1999–2002, five sampling cruises have been carried out on Lake Balaton to assess trace metal distribution in the lake and to identify major sources. Eighteen elements, including Cr, Co, Ni, Cu, Zn, Cd, Pb (trace metals) and Al, Ba, Ca, Fe, K, Mg, Mn, Na, P, S, Sr (major metals), were determined in one or more of the lake's compartments. Lower trace metal concentrations in rainwater were observed in June and February 2000, while much higher levels were present in September 2001 (during a storm event) and in snow (February 2000). In the Northern and Western parts of the lake, especially at the inflow of river Zala and the locations of the yacht harbours, metal concentrations were higher in almost all compartments. Because the lake is very shallow, storm conditions also change significantly the metal distributions in the dissolved and particulate phases. The Kis-Balaton protection system located on Zala river functions very efficiently for retaining suspended particulate matter (SPM; 72% retention) and associated metals. Metal concentrations in surface sediments of the lake showed a high variability. After normalisation for the fine sediment fraction, only a few stations including Zala mouth appeared to be enriched in trace metals. In zooplankton, Zn seemed to be much more elevated compared to the other trace metals. Based on the molar ratios of the trace metals in the various compartments and input flows of the lake, several trends could be deduced. For example, molar ratios of the trace metals in the dissolved and solid (suspended particulate matter and sediments) phases in the lake are fairly similar to those in Zala River.

Keywords: Heavy metals; Rainwater; Dissolved phase; Suspended particulate matter; Zooplankton; Sediment; Lake Balaton

1. Introduction

Lake Balaton is the largest lake in Central Europe with a surface area of 596 km^2 and an average depth of 3.2 m (Hlavay and Polyák, 2002). Half of the lake's catchment area is drained by Zala river, which crosses

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areas of intensive agriculture and a county with rapidly growing population density and industrial activities. The sewage treatment plant of the town of Zalaegerszeg, for example, was an important source of SPM (suspended particulate matter) to Zala river. As a result, large amounts of nutrients, organic compounds, heavy metals and suspended particulate matter (SPM) were supplied to the lake. Besides aquatic inputs, Lake Balaton is also exposed to atmospheric pollution from the same activities that cause aquatic pollution.

Identification and quantification of trace metal sources to Lake Balaton, as well as the fate of those trace metals in that ecosystem, are important environmental scientific issues. Earlier studies on the lake tackled some of these aspects, but most of them focussed only on metals in sediments, including their speciation, distribution and mobility (Hlavay and Polyák, 1998; Weisz et al., 2000), with the exception of the study of Elbaz-Poulichet et al. (1997) on biogeochemistry of trace metals in the western basin of the lake. Metal concentration changes in Zala river (Salánki et al., 1992) and in other small tributaries around the lake (Hlavay and Polyák, 2002) also focussed on sediments. As a result, a general picture of the metal sources, their distribution in and between the various compartments of the lake and their bioavailability are not, or only to a limited extent, available.

This paper is part of a series dealing with major sources trace metals of trace metals to Lake Balaton as well as their behaviour in the lake (e.g., Nguyen et al., 2004a,b). Different compartments of the lake (dissolved, particulate, biological materials, sediments and atmosphere) were sampled at specific times between 1999 and 2002. In addition, we discussed (1) the impact of weather conditions on the distribution of heavy metals between the various compartments of the lake, (2) potential sources of pollutants to the lake such as rivers (Zala River) and atmosphere (precipitation) and (3) the effectiveness of the Kis-Balaton system to prevent suspended particulate matter (SPM) and pollutants from entering the lake. In a subsequent paper, the interactions between the various compartments of the lake are described. For that purpose, statistical tools such as principal component analysis and cluster analysis were used, allowing a better understanding of the trace metals behaviour in the lake.

2. Materials and methods

2.1. Sampling

2.1.1. Atmospheric depositions

Rain and snow samples were collected in February and June 2000 and September 2001 at the Siófok station of the Hungarian Meteorological Service, situated on the southern shore of Lake Balaton. The sampling system included a polyethylene (PE) funnel (28 cm diameter) suspended on a wooden holder, and a recipient PE bottle (Kartell, Italy) placed on the grass behind the meteorological station, near the lake shore, and was operated manually. Both funnel and recipient bottle were precleaned subsequently with detergent, water, nitric acid, Milli-Q water, and soaked in 2% nitric acid until use. Unfiltered samples were acidified to 0.2% (v/v), using concentrated nitric acid (Merck, suprapur).

2.1.2. Surface water

Water samples were taken at 19 stations covering Lake Balaton during two main expeditions, organized in June 2000 and September 2001. An extra survey was carried out in August 2002 at Zala River and Kis-Balaton retention system, which was built on the lower part of the main inflow Zala River. It started functioning in 1985 and appeared to be a fairly efficient system regarding the retention of nutrients and SPM. All sampling points are shown in Fig. 1. Sampling details for each expedition are as follows:

In June 2000 (calm weather conditions), 14 stations (Kes, E1, E2, X, E3 in the Northern part; M, K, G, A, E in the middle part; Zala mouth, D5, D6, D7 in the Southern part of the lake) were sampled. In September 2001 (calm as well as stormy weather conditions), water of 15 near-shore stations (Kes, Y, E1, E2, A′, X, E3, E′ in the Northern part; Zala mouth, D2, D3, D5, D6, S, D7 in the Southern part of the lake) was collected. In August 2002 (calm weather conditions), water was sampled at four stations along the Zala river: Z1 (located in the upper part, at Zalaapáti, downstream the largest city of the catchment area, Zalaegerszeg), Z2 (in the first retention pond of Kis-Balaton), Z3 (in the outlet of the first retention pond) and Z4 (in the outlet of the second pond at Feneki, close to Zala mouth).