

Lead, arsenic, cadmium and copper in Lake Asososca, Nicaragua

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Received 2 November 1993; accepted 14 January 1994

Abstract

The present study of lead, arsenic, cadmium and copper was carried out between July 1991 and April 1992 in the water and sediment of Lake Asososca. The concentrations of lead in water were within normal limits for drinking water, but significant differences from month to month were found. No significant difference was found either between the concentrations at each sample station or between the concentrations at each sample depth. Arsenic concentrations were within a relatively normal range, but the concentrations in July was significantly lower than in the rest of the year. Cadmium and copper concentration levels were normal. In the superficial sediment of the lake, the cadmium and copper concentration levels were similar in the whole lake. The lead and arsenic contents in sediment were significantly higher at the pumping station than at the rest of the sampling points.

Keywords: Lead; Arsenic; Cadmium; Sediment; Water; Lake

1. Introduction

Lake Asososca is formed in a dormant volcanic crater 35 m above sea level to the west of the City of Managua, Nicaragua. The surface area of the lake is 736 000 m², north-south diameter, 800 m, east-west diameter, 1000 m, and maximum depth, 91 m. It has an estimated volume of 40 million m³ [1]. Lake Asososca is an important source of drinking water for approximately 30% of Managua's population [2].

Probable sources of contamination by heavy metals in Lake Asososca could be a chlor-alkali

plant, a pesticide factory and various refineries, all located in the area surrounding the lake. Another possible contamination source could be the toxic gases from the vehicles driving on the highway close to the lake. The volcanic origin of the lake could also elevate the concentration of arsenic.

The objective of this study was to quantify the concentrations of lead, arsenic, cadmium and copper in water and sediment from Lake Asososca.

2. Experimental

2.1. Water

Sampling was carried out every 3 months

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between July 1991 and April 1992. Water samples in duplicate were taken in Van Dorn bottles at three different depths, surface, intermediate and bottom, at five sample stations (Fig. 1). The samples were preserved with 2 ml HCl (37%) and kept in polyethylene bottles at 4°C until analysis.

Palladium chemical modifier ($500 \text{ mg}\cdot\text{l}^{-1}$), 0.25 ml ascorbic acid (0.25%) and 0.25 ml nitric acid (65%) were added to prepare the samples for analysis of lead and cadmium [3]. The samples were analyzed in a Varian SpectrAA-20 atomic absorption spectrophotometer with a GTA-96 graphite furnace. Detection limit for lead was $0.94 \text{ }\mu\text{g}\cdot\text{l}^{-1}$, and for cadmium $0.2 \text{ }\mu\text{g}\cdot\text{l}^{-1}$.

The total amount of arsenic in water was determined by digesting 100 ml sample with 10 ml hydrochloric acid [4], adding 10 ml potassium iodide (10%), bringing up to 100 ml with distilled water, and subsequently reading in a Varian SpectrAA-20 atomic absorption spectrophotometer with a vapor generating accessory VGA-76. A calibration standard with a concentration of $400 \text{ }\mu\text{g As}\cdot\text{l}^{-1}$ was used to stabilize the drierite trap system before analysis [5]. The detection limit with this method was $1.7 \text{ }\mu\text{g As}\cdot\text{l}^{-1}$. Arsenic

samples with known concentrations were prepared to control the reproducibility ($\pm 3.36\%$) of the method. The recovery of samples with added known amounts of arsenic was 106.64–123.24%.

For the analysis of copper in water, digestion with hydrochloric acid was performed in the same way as for arsenic. The pH was adjusted to 7–8 before carrying out extraction with APDC and MIBK [6]. The samples were centrifuged at 4000 rev./min for 5 min to separate the aqueous and the organic phase. The samples were read at a wavelength of 324.8 nm in an atomic absorption spectrophotometer with graphite furnace. Samples with a standard-I ICP multi-element solution of $7.5 \text{ }\mu\text{g Cu}\cdot\text{l}^{-1}$ were prepared to control the accuracy of the method, which was found to be $\pm 1\%$. The relative standard deviation of the method was $\leq 5.9\%$ and the detection limit was $0.26 \text{ }\mu\text{g Cu}\cdot\text{l}^{-1}$.

2.2. Sediment

The surface (0–5 cm) sediment samples were collected in duplicate with an Ekman dredge at the same five stations as the water samples (Fig. 1). The samples were centrifuged, dried at room

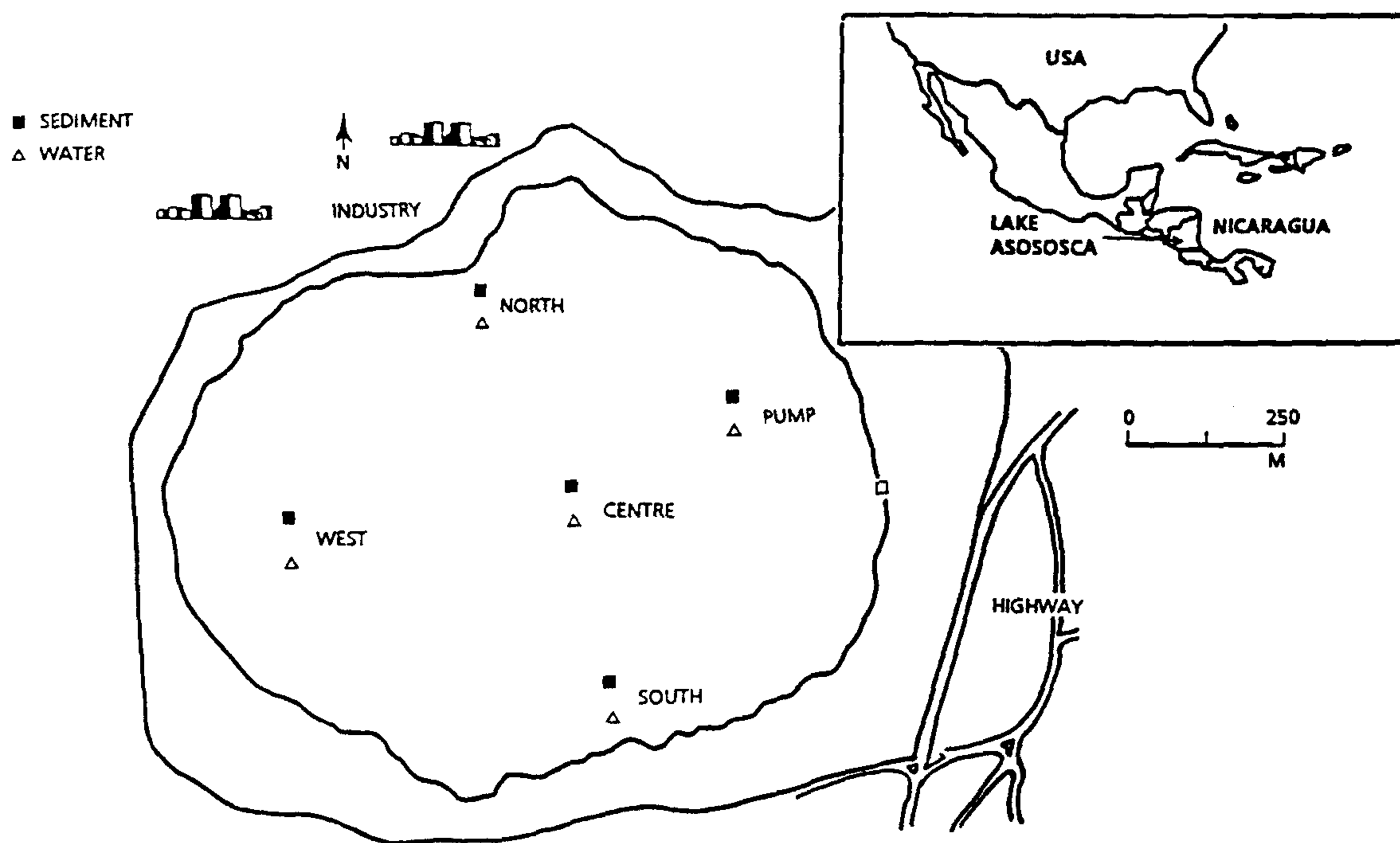


Fig. 1. Sample stations for Pb, As, Cd and Cu in water and sediment from Lake Asososca, Nicaragua.

temperature, macerated and stored in polythene bottles until analysis. For the analysis of lead, cadmium and copper, the sediment samples were leached. A 1.5-g portion of dried sample was weighed, a mixture of 1:3 HNO₃/conc. HCl was added and the sample was digested in a water bath at 80°C for 1 h with constant agitation. The samples were made up to 100 ml with distilled water. Calibration curves of 1–5 mg Pb·l⁻¹, 0.5–5 mg Cd·l⁻¹ and 1–5 mg Cu·l⁻¹ were prepared. The accuracy and relative standard deviation of the method were controlled by analyzing certified NBS 2704 River Sediment Samples for each of the elements (Table 1). The detection limits were 1.8 mg Pb·kg⁻¹, 0.83 mg Cd·kg⁻¹ and 2.8 mg Cu·kg⁻¹.

Arsenic in sediment was analyzed by the method of hydride generation [7] using a VGA-76 Vapor Generator. A 0.25-g sample was digested with 37% HCl and hydrogen peroxide (30%) in a water bath at 90–100°C [8] and brought up to 100 ml with distilled water. The prepared samples were read in the atomic absorption spectrophotometer as described for the water samples. The detection limit obtained was 0.11 mg As·kg⁻¹.

3. Results and discussion

3.1. Water

The results obtained for lead analysis in the water from Lake Asososca are shown in Table 2. Natural lead concentrations in river and lake water fluctuate between 1 and 10 µg Pb·l⁻¹ [9]. All our results were in the same natural range. Much higher levels of lead in water frequently occur near highways and cities as a result of gasoline combustion [10], but this was not the case in Lake Asososca. The permissible limit for lead in drinking water is 50 µg Pb·l⁻¹ [11].

When a certain number of values are below the detection limit, as in this case, McBean and Rovers [12] recommend replacing these values with data equal to: (a) the detection limit, (b) half of the detection limit and/or (c) zero, and carrying out an analysis of variance in the three cases. A multi-factorial analysis of variance applied to the concentrations that were found both according to (a) and (b) demonstrated a significant difference between months but did not show differences between sample stations or between depths. The concentrations of total lead in water in the months of July and October were less than those found in January and April. This difference is probably due to the fact that July and October are in the rainy season and the concentration of the metal is diluted.

Table 3 shows the results of cadmium analysis in water from Lake Asososca. Cadmium concentrations vary from ≤ D.L.–1.1 µg·l⁻¹ and indicate that the concentrations are within natural levels for cadmium in water, ≤ 1 µg·l⁻¹ [9]. Cadmium values in uncontaminated waters from the Remote stream (California) vary from 0.01–0.1 µg·l⁻¹ [13]. The permissible limit for cadmium in drinking water according to the Panamerican Health Organization is 5.0 µg Cd·l⁻¹ [11]. Most of the cadmium data in water from Lake Asososca were below the detection limit and for this reason no statistical analysis was carried out.

The concentrations of arsenic in the lake can be seen in Table 4. These fluctuated between ≤ D.L.–15.77 µg·l⁻¹ and the mean of the concentrations was 5.86 µg·l⁻¹. The arsenic value recommended by the Panamerican Health Organization as a guide for drinking water is < 50.0 µg·l⁻¹ [11]. Natural values of arsenic in water

Table 1
Lead, cadmium, copper and arsenic concentrations (µg·g⁻¹) in certified NBS and EPA sediment samples

Sample	Pb	Cd	Cu	As
NBS 2704	161 ± 17	3.45 ± 0.22	98.6 ± 5.0	—
EPA	—	—	—	4.19
Present study	172	3.3	106	4.1
Present study (% S.D.)	≤ 3.2	≤ 10.2	≤ 2.8	≤ 3.5

Table 2
Total lead concentrations (mean values of duplicates, $\mu\text{g}\cdot\text{l}^{-1}$) in water from Lake Asososca, Nicaragua

Sample	Depth	Month			
		July 91	Oct 91	Jan 92	April 92
Centre	S	1.24	< D.L.	1.53	< D.L.
	I	1.58	< D.L.	3.78	2.46
	B	1.58	< D.L.	8.69	2.90
West	S	1.13	1.09	1.29	9.78
	I	1.05	< D.L.	9.95	1.18
	B	15.67	< D.L.	3.12	7.29
North	S	< D.L.	< D.L.	1.77	10.40
	I	< D.L.	< D.L.	8.33	8.7
	B	8.48	0.95	4.97	11.94
Pump	S	< D.L.	< D.L.	1.14	< D.L.
	I	8.06	< D.L.	2.82	9.92
	B	1.43	2.24	4.30	1.55
South	S	< D.L.	2.61	1.38	10.85
	I	< D.L.	1.27	1.28	9.77
	B	18.07	0.81	2.56	9.89

Sample depths: S, surface; I, intermediate; B, bottom; D.L., detection limit.

are $\leq 10 \mu\text{g}\cdot\text{l}^{-1}$. In previous unpublished studies, we detected a concentration of $25 \mu\text{g As}\cdot\text{l}^{-1}$ in Lake Monte Galán (Nicaragua) which is another lake of volcanic origin without anthropogenic contamination. A multi-factorial analysis of variance applied to the data for total arsenic in

water showed that the concentration in July is significantly lower than in the other months. It is probable that, as with lead, the concentration of arsenic in this month has been diluted as a result of precipitation. In October, the precipitation did not result in a similar reduction in arsenic con-

Table 3
Total cadmium concentrations (mean values of duplicates, $\mu\text{g}\cdot\text{l}^{-1}$) in water from Lake Asososca, Nicaragua

Sample	Depth	Month			
		July 91	Oct 91	Jan 92	April 92
Centre	S	0.35	< D.L.	< D.L.	0.24
	I	0.79	< D.L.	< D.L.	< D.L.
	B	< D.L.	< D.L.	< D.L.	< D.L.
West	S	0.62	0.22	< D.L.	< D.L.
	I	0.7	< D.L.	< D.L.	< D.L.
	B	0.61	< D.L.	< D.L.	< D.L.
North	S	1.13	1.03	< D.L.	< D.L.
	I	0.95	1.12	< D.L.	< D.L.
	B	0.76	0.5	< D.L.	< D.L.
Pump	S	< D.L.	< D.L.	< D.L.	< D.L.
	I	< D.L.	< D.L.	< D.L.	< D.L.
	B	< D.L.	< D.L.	< D.L.	< D.L.
South	S	0.55	0.20	< D.L.	< D.L.
	I	0.70	0.24	< D.L.	< D.L.
	B	0.82	< D.L.	< D.L.	< D.L.

Sample depths: S, surface; I, intermediate; B, bottom; D.L., detection limit.

Table 4
Total arsenic concentrations (mean values of duplicates, $\mu\text{g}\cdot\text{l}^{-1}$) in water from Lake Asososca, Nicaragua

Sample	Depth	Month			
		July 91	Oct 91	Jan 92	April 92
Centre	S	1.68	7.48	5.36	6.91
	I	0.85	8.39	5.85	7.12
	B	5.7	6.87	6.27	6.41
West	S	4.07	7.13	5.85	5.97
	I	6.36	7.88	5.63	5.02
	B	0.85	3.23	5.71	11.22
North	S	0.85	5.49	5.06	6.53
	I	4.22	9.21	5.59	5.52
	B	5.45	11.74	5.83	5.67
Pump	S	0.85	4.36	6.26	6.37
	I	4.04	8.34	5.98	5.63
	B	6.28	3.23	5.17	5.89
South	S	3.02	7.24	1.98	5.64
	I	6.38	7.20	5.99	5.89
	B	15.77	7.91	5.70	8.11

Sample depths: S, surface; I, intermediate; B, bottom; D.L., detection limit.

centration in the lake. The precipitation in this period could have carried arsenical compounds from the volcanoes into the lake.

The results of copper analysis in water from Lake Asososca (Table 5) varied between \leq D.L.– $13.06 \mu\text{g}\cdot\text{l}^{-1}$ and were typical concentra-

tions for uncontaminated water. The mean was $3.10 \mu\text{g}\cdot\text{l}^{-1}$. The value recommended by the Panamerican Health Organization as a guide is $\leq 1000 \mu\text{g Cu}\cdot\text{l}^{-1}$, based on the organoleptic quality of the water [11]. Concentrations in uncontaminated fresh water vary from 0.5 to ≥ 2

Table 5
Total copper concentrations (mean values of duplicates, $\mu\text{g}\cdot\text{l}^{-1}$) in water from Lake Asososca, Nicaragua

Sample	Depth	Month			
		July 91	Oct 91	Jan 92	April 92
Centre	S	< D.L.	0.62	1.77	5.06
	I	1.72	1.24	0.88	1.05
	B	2.83	6.18	0.92	12.03
West	S	< D.L.	3.24	1.48	0.30
	I	2.74	3.78	0.82	0.65
	B	12.96	2.84	1.22	0.31
North	S	< D.L.	1.22	1.55	0.35
	I	< D.L.	2.14	1.52	< D.L.
	B	9.36	7.10	2.42	0.44
Pump	S	< D.L.	3.22	0.67	0.70
	I	13.06	11.46	2.29	< D.L.
	B	< D.L.	4.00	5.67	0.42
South	S	< D.L.	8.40	1.06	< D.L.
	I	3.06	3.86	0.71	0.62
	B	< D.L.	8.24	2.17	0.76

Sample depths: S, surface; I, intermediate; B, bottom; D.L., detection limit.

$\mu\text{g}\cdot\text{l}^{-1}$ [1]. Multi-factorial analysis of variance was performed on the copper results in water and no significant difference was found between stations, depths and months.

The total concentrations in water of the four elements analyzed in Lake Asososca were compared with values reported by different authors (Table 6) and the concentrations in Asososca are similar to the natural concentrations in lakes and rivers from various parts of the world.

3.2. Sediment

The values of the four elements found in sediment are shown in Table 7. The concentrations of lead in the sediment were in the range 21.07–57.22 $\text{mg}\cdot\text{kg}^{-1}$; this is considered normal in nature. Values in the range 2–50 $\text{mg}\cdot\text{kg}^{-1}$ have been reported from uncontaminated areas [10]. An analysis of variance of a factor of one presented a significant difference between the sample stations, the value at station 4 (Pump) being the

highest. This value probably results from the small grain size texture of the sediment at this station: finer sediments, or those of smaller grain size, possess a greater capability for accumulating heavy metals than those of coarser grain size [19].

The cadmium content in the surface sediment of Lake Asososca was homogeneous at the five sampling stations at a level of 2.1–3.9 $\text{mg}\cdot\text{kg}^{-1}$, which demonstrates that there has not been any anthropogenic contamination. Cadmium concentrations in pre-industrial sediments from lakes in Wisconsin [20] were 1.7 $\text{mg}\cdot\text{kg}^{-1}$.

The arsenic concentrations in the sediment were homogeneous except in the Pump sampling station (16.54 $\text{mg}\cdot\text{kg}^{-1}$) where, as with the lead, the relatively high value is probably due to the texture of the sediment. As the reworking of the sediment due to the constant extraction of water by the Nicaraguan Water Supply Company (INAA) is the principal characteristic of this station, sediment from the lowest layer is probably

Table 6

Comparison of the concentrations ($\mu\text{g}\cdot\text{l}^{-1}$) of Pb, Cd, As and Cu in Lake Asososca with natural concentrations from other countries

Element	Concentration	River and/or lake	Reference
Pb	1.5	Lake Michigan, USA	[14]
	4.0	Lake Asososca, Nicaragua	Present work
	2–4	River Danubio, Austria	[15]
Cd	0.07–2.6	River Danubio, Austria	[15]
	0.2	Lake Asososca, Nicaragua	Present work
	0.3	Lake Michigan, USA	[16]
As	1.0	Lake Michigan, USA	[16]
	5.8	Lake Asososca, Nicaragua	Present work
	800	River Antofagasta, Chile	[17]
Cu	2–5	River Neckar, USA	[18]
	3.1	Lake Asososca, Nicaragua	Present work

Table 7

Total lead, cadmium, arsenic and copper concentrations (mean values of duplicates, $\text{mg}\cdot\text{kg}^{-1}$) in surface sediments from Lake Asososca, Nicaragua

Station	Lead	Cadmium	Arsenic	Copper
Centre	35.4	2.3	7.8	53.3
West	36.6	3.3	7.8	36.6
North	28.6	2.2	2.6	62.6
Pump	57.2	3.9	16.5	73.3
South	21.1	2.6	5.3	54.2

incorporated into the surface layer. This could also elevate the concentrations. Natural concentrations of arsenic in sediment from 10 lakes in Saskatchewan (Canada) were $2.7\text{--}13.2\text{ mg}\cdot\text{kg}^{-1}$ [21].

The results of total copper in surface sediments from Lake Asososca were uniform at the five sample stations and their concentrations were considered to be within normal limits. Copper concentrations in sediments of natural origin are found in the range $3\text{--}76\text{ mg}\cdot\text{kg}^{-1}$ in the St. Lawrence estuary [22] on the continental shelf of southeastern USA ($\leq 2\text{ mg}\cdot\text{kg}^{-1}$) [23], and in Arctic lakes in Canada ($7\text{--}62\text{ mg}\cdot\text{kg}^{-1}$) [24].

4. Conclusions

As a result of the low concentrations of the four metals analyzed in water and sediments of Lake Asososca, we may conclude that the industries surrounding the lake have not affected the quality of the water up to now, as far as heavy metals are concerned. Nonetheless, monitoring should also be carried out in the future, in order to control the quality of the lake water and to watch for possible increases in heavy metal concentrations because of their toxicity even in small quantities.

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