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# Total Arsenic in Water, Fish, and Sediments from Lake Xolotlán, Managua, Nicaragua

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In recent years there has been increasing concern over arsenic in aquatic environments from such sources as arsenical pesticides, smelters, coal-fired power plants and erosion caused by extensive land use. Another important contribution to As in the environment is the release associated with volcanic activity and hot springs (Ferguson & Gavis 1972).

Lake Xolotlán has a surface area of 1000 $km^2$. The content of arsenic in Lake Xolotlán has different origins, such as volcanic activity in the area, waste water from a geothermal plant situated in the Momotombo Volcano on the northwest coast of the lake and a high number of hot springs (Terán & Incer 1964).

The objective of the present study was to determine total As in water, sediments and fish in Lake Xolotlán at different sampling sites.

## MATERIALS AND METHODS

Water surface samples were collected with a van Dorn sampler at 18 stations in the lake (three samples at each station), at 3 stations inside the geothermal plant (separated well water which is reinjected and waste water), and directly from the hot spring in Tipitapa (Fig. 1), all taken on the same day. Samples of one liter were preserved with 2 ml of 12 N HCl (All reagents used were analytical grade). An aliquot of 100 ml of the preserved sample was acidified with 10 ml of 12 N HCl before concentrating to 20 ml at 85°C. The concentrated samples were reduced with potassium iodide 10%w/v (Le Houillier 1986) and diluted to 100 ml. The samples were analyzed for total As using a VARIAN SpectrAA-20 atomic absorption spectrophotometer with a vapor generating accesory VGA-76. The detection limit was 1.7 $\mu g \cdot l^{-1}$.

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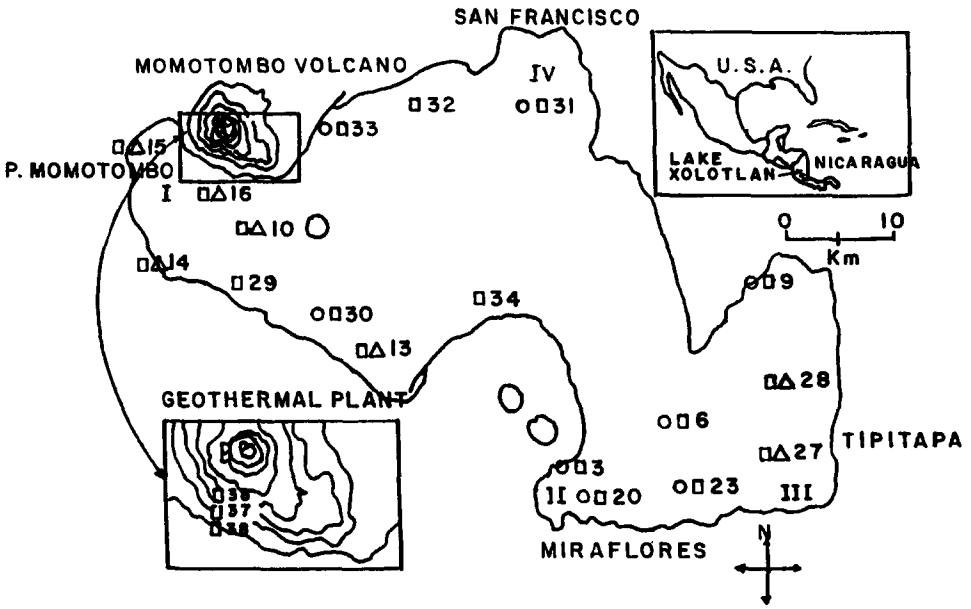


□ Water
○ Sediments with Ekman Dredge
△ Sediments with core sampler
I to IV Fish

Figure 1. Sampling sites for arsenic in water, fish and sediments in Lake Xolotlán

Recoveries of spiked samples averaged 107 ± 13%. The SD% for duplicate samples was ≤5%.

Samples of the two most consumed cichlids, Cichlasoma citrinellum (47 individuals) and Cichlasoma managüense (97 individuals), were collected with the help of local fishermen at four localities (Fig.1). The samples were stored at -18°C until analysis. One g of muscle tissue from each individual was calcinated at 450°C using a dry ashing technique with magnesium nitrate hexahydrate as an ashing aid (USDA 1981). The ash was then dissolved in 10 ml of 12 N HCl, reduced with potassium iodide and diluted to 100 ml for total arsenic analysis as described for the water samples. The detection limit was 0.011 $\mu g \cdot g^{-1}$. Recoveries of spiked samples averaged 105 ± 16%. The SD% for duplicate analysis was ≤6%.

The top layers of sediments (0-15 cm) were collected twofold with an Ekman dredge at each of 8 stations (Fig. 1). At 7 other stations (Fig. 1) the samples were taken with a core sampler and divided into 5 cm segments. All samples were dried at room temperature, powdered and

stored in polyethylene bottles at room temperature until analysis. An amount of 0.25 g was digested with 5 ml of conc. HCl and 0.5 ml of $H_2O_2$ 37% (Moffet 1988). The digest was reduced with potassium iodide and diluted to 100 ml for total arsenic analysis as described for the water samples. The detection limit was 0.11 $\mu g \cdot g^{-1}$ . The SD% for duplicate analysis was ≤6%. To test the accuracy of the digestion method, EPA municipal digested sludge and NBS river sediment 2704 were analyzed. The relative error was less than 9.2%. Recoveries of spiked samples averaged 96 ± 26%.

## RESULTS AND DISCUSSION

Mean As concentrations in the surface water ranged between 10.23 - 30.13 $\mu g \cdot l^{-1}$ (Table 1). The concentrations at the sampling sites on the northern part of the lake were the highest, except at the two sites 15 and 16 (one-way ANOVA). The concentrations found at the three waste water sampling sites inside the geothermal plant were extremely high (5295 - 16700 $\mu g \cdot l^{-1}$), compared to the concentrations in the lake. In the Tipitapa hot spring the concentration of 206 $\mu g \cdot l^{-1}$ was about 10 times higher than the mean value in the lake.

The higher concentrations found at five of the seven northern sampling sites (10, 14, 31, 32 and 33) may be due to the effluents from the geothermal plant. Owing to the great volume ($8 \cdot 10^9$ $m^3$) of Lake Xolotlán, this influence is still very small compared to the influence that other geothermal plants have had on the reservoirs that receive their waste water, i.e., in Japan 18 - 40 $mg \cdot l^{-1}$ (Nakahara et al. 1978) and in El Salvador 8.9 $mg \cdot l^{-1}$ (Jernelöv et al. 1976). The reason that the As level at sites 15 and 16 do not show an increasing level could be due to the currents which probably carry the arsenic towards the other sampling sites. Another reason for the higher concentrations at the northern sampling sites could be the presence of an unknown number of hot springs inside the lake (Parson Corporation 1972).

In Nicaragua the arsenic content of surface water in lakes of volcanic origin where there has been no anthropogenic contamination at all was 25.15 $\mu g \cdot l^{-1}$ (Lake Montegalán ) and 78.15 $\mu g \cdot l^{-1}$ (Lake Asososca-León) (Cruz 1991, personal communication). Other ecosystems of volcanic origin have much higher natural levels. In Antofagasta, Chile the average arsenic concentration in a river water supply of drinking water was 0.8 $mg \cdot l^{-1}$ (Borgoño and Greiber 1972). In the region of Cordoba, Argentina, Argüello et al. (1938) reported maximum values of between 0.9 and 3.4 $mg \cdot l^{-1}$.

Table 1. Total arsenic concentrations in water from Lake Xolotlán, the Tipitapa hot spring and the geothermal plant ($\mu g \cdot l^{-1}$).

| | Sample sites | n | Mean | SD% |
|---|---|---|---|---|
| 3 | Miraflores | 3 | 14.00 | 0.70 |
| 6 | Pto. Huete, in front of | 3 | 15.76 | 0.25 |
| 9 | Bahía San Antonio | 3 | 15.40 | 1.64 |
| 10 | Momotombito | 3 | 25.90 | 2.32 |
| 13 | Mateare | 3 | 20.00 | 7.03 |
| 14 | La Zopilota | 3 | 26.36 | 5.89 |
| 15 | Puerto Momotombo | 3 | 19.40 | 10.27 |
| 16 | Pta. La Salinita | 3 | 16.00 | 3.03 |
| 20 | Isla del Amor | 3 | 20.53 | 7.42 |
| 23 | Rubén Darío | 3 | 14.47 | 1.61 |
| 27 | Tipitapa | 3 | 10.23 | 0.37 |
| 28 | La Compañía | 3 | 11.93 | 0.15 |
| 29 | El Boquerón | 3 | 16.23 | 4.62 |
| 30 | La Estación | 3 | 13.90 | 3.60 |
| 31 | Santa Graciela | 3 | 29.97 | 0.61 |
| 32 | San Francisco | 3 | 28.47 | 0.11 |
| 33 | Isla Rosa | 3 | 30.13 | 0.15 |
| 34 | Pta. Chiltepe | 3 | 15.36 | 2.30 |
| 35 | Tipitapa hot spring | 1 | 206 | |
| 36 | Separated water 1650 m | 1 | 16700 | |
| 37 | Separated water 488 m | 1 | 5295 | |
| 38 | Res. water to the lake | 1 | 12000 | |

The arsenic content of surface waters in unpolluted areas with no volcanic activity varies, but typical values according to the literature seem to be a few micrograms per liter or less. An average value of 3 $\mu g \cdot l^{-1}$ in lake water was found in Germany ( Quentin & Winkler 1974) and a mean arsenic concentration of 2.5 $\mu g \cdot l^{-1}$ was reported in some Norwegian rivers (Lenvik et al. 1978).
The As levels in the Lakes Xolotlán, Montegalán and Asososca-León of Nicaragua are not very high compared to ecosystems in other countries with volcanic activity

Table 2. Total arsenic concentrations in fish muscle tissue from Lake Xolotlán ($\mu g \cdot g^{-1}$ wet weight).

| Sample sites | Species | n | Range |
|---|---|---|---|
| I Pto. Momotombo | C. citrinellum | 12 | <0.01-0.29 |
| I Pto. Momotombo | C. managüense | 29 | <0.01-0.24 |
| II Miraflores* | C. managüense | 21 | <0.01-0.20 |
| III Tipitapa | C. citrinellum | 17 | <0.01-0.37 |
| III Tipitapa | C. managüense | 18 | <0.01-0.12 |
| IV San Francisco | C. citrinellum | 18 | <0.01-0.23 |
| IV San Francisco | C. managüense | 29 | <0.01-0.23 |

*No C. citrinellum could be captured at this sampling site.

and/or geothermal plants. The reason for that could only be found through more extensive studies.

The total arsenic concentrations in muscle of the two fish species at the four sampling sites ranged between <0.01 - 0.37 $\mu g \cdot g^{-1}$ wet weight (Table 2). These sample values are normal for fish from unpolluted or mildly contaminated waters where As levels generally range from <0.1 -0.4 $\mu g \cdot g^{-1}$ wet weight (Moore and Ramamoorthy 1984).

The World Health Organization (WHO 1981) recommends an acceptable daily intake (ADI) of 2 $\mu g$/kg body weight/day for humans. This means that under conditions of normal consumption, the arsenic content in the fish from Lake Xolotlán will probably not have any toxic effect on humans who consume these fish (Centro Panamericano Ecología Humana y Salud 1987).

According to the U.S.EPA (1980), the LC50/EC50 for As for a number of freshwater fish lies between 13 - 41 $mg \cdot l^{-1}$. The mean concentration in the fish from Lake Xolotlán is about 1000 times less, thus we expect no toxic effect on fish due to arsenic.

Arsenic concentrations in surface sediments ranged between 5.37 - 8.65 $\mu g \cdot g^{-1}$ dry weight (Table 3). A one-way ANOVA showed that there were no significant differences between concentrations at the surface points. In the analysis made at varying depths (Table 4), a two-way ANOVA showed that there were no significant differences between depths, but concentrations at station 28 were significantly higher than the other stations.

Table 3. Total arsenic concentrations in surface sediments from Lake Xolotlán ($\mu g \cdot g^{-1}$ dry weight).

| Samplesites | n | Mean |
|---|---|---|
| 3 Miraflores | 2 | 6.75 |
| 6 Pta. Huete, in front of | 2 | 6.71 |
| 9 Bahía San Antonio | 2 | 5.64 |
| 13 Mateare | 2 | 5.59 |
| 20 Isla del Amor | 2 | 5.27 |
| 23 Rubén Darío | 2 | 8.64 |
| 27 Tipitapa | 2 | 5.35 |
| 28 La Compañía | 2 | 7.53 |
| 30 La Estación | 2 | 8.65 |
| 31 Santa Graciela | 2 | 5.97 |
| 33 Isla Rosa | 2 | 7.26 |

Table 4. Total arsenic concentrations in sediments at various depths at some sampling sites in Lake Xolotlán ($\mu g \cdot g^{-1}$ dry weight).

| Depth / Site | 0- 5cm | 5-10cm | 10-15cm | 15-20cm | 20-25cm |
|---|---|---|---|---|---|
| 10 | 3.80 | 4.23 | 6.13 | 5.34 | 5.81 |
| 13 | 5.59 | 6.97 | 7.23 | 5.49 | 5.67 |
| 14 | 4.40 | 5.97 | 7.64 | 6.14 | 4.03 |
| 15 | 6.87 | 8.57 | 6.82 | 7.63 | 6.63 |
| 16 | 4.50 | 5.64 | 5.62 | 6.15 | 5.91 |
| 27 | 5.35 | 5.23 | 5.34 | 4.60 | 5.35 |
| 28 | 7.53 | 8.94 | 10.43 | 10.44 | 9.76 |

The higher concentration found at site 28 may be due to the existence of the geothermal source in Tipitapa where a value of 206 $\mu g \cdot l^{-1}$ was found in water and probably also due to the composition of the sediment (clay) (IRENA 1987). The fact that the surface distribution is homogenous and that the overall level is similar to

concentrations found in unpolluted lakes in the USA and Canada (Lake Michigan 5.23 - 9.2 $\mu g \cdot g^{-1}$ dry weight, 10 Saskatchewan lakes 2.7 -13.2 $\mu g \cdot g^{-1}$ dry weight - Moore & Ramamoorthy 1984) suggests that the exploitation of the Momotombo Volcano through operation of the geothermal plant, which began in 1982, has not had any influence yet on the total arsenic concentration in the sediments. This statement is supported by the values obtained at varying levels at sampling sites 10, 14, 15 and 16 (Table 4). The sediment depositional rate in Lake Xolotlán is unknown but must be abnormally high due to an evaporation/precipitation ratio of 2:1 and to the lack of superficial outlets (Montenegro 1991). If this was not so, the influence of arsenic concentrations as input from the geothermal plant would have caused a significant increase in the As levels in the surface sediment areas closest to the volcano.

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