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Degree of Pollution in Water and Sediments of As, Cd, Cr, Cu, Pb and Zn in Valsequillo Dam, Puebla City, México

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Abstract. The present study is to determine the concentration of metals, As in water and sediments in an semi-rural area with influence urban-industrial output in the south of metropolitan area of Puebla City, Mexico at the Valsequillo Dam. The concentration of 7 trace elements (As, Cd, Cr, Cu, Pb, Ni and Zn) was determined in 11 water and sediment samples. The concentration pattern in water indicates low concentrations and is virtually observed in water. However, the sediments indicate high concentrations of these elements; which is confirmed by the higher values of Geoacumulation Index (Igeo).

Keywords: Metal pollution, Igeo, Valsequillo Dam, Mexico.

1. Introduction

Metals and metalloids are essential for life, but others can also be very harmful and are also considered as the first toxic elements known to man [1]-[3]. Due to the cumulative nature these metals and non- metals are often found not only in the various environmental compartments (air , water, soil , flora and fauna) but are also detected in the human body [4], [5]. The results of the various researches show that the surface water and sediments in different water bodies represent a complex system of natural and anthropogenic substances in which numerous physical , chemical and biological processes affect their space-time distribution of substances in water-sediment system [6], [7]. Metals and metalloids are pollutants that are absorbed in the sediments from the water bodies, resulting in a progressive increase in their concentrations over time, and are subsequently accumulated in organisms that are part of those ecosystems. [8].

The concentration of trace elements in sediments is often used to reveal the history and intensity of local or regional pollution [9]. Therefore, an assessment of metals in contaminated sediment is an indispensable tool for determining risk in an aquatic environment [10]. The sediment quality indices are used to infer the potential contamination content in sediments and their biological effects. These indices assess the extent to which they are chemically associated with the sediment and can have an adverse effect on the aquatic organisms. In addition, they are also useful to classify and prioritize the contaminated areas for further investigation [11].

2. Methods

2.1. Study Area

The municipality of Puebla has 524.31 km^2 and 2,668,347 inhabitants are located within the Atoyac River Basin which drains flowing into the Valsequillo Dam and Alseseca River is one of the main streams

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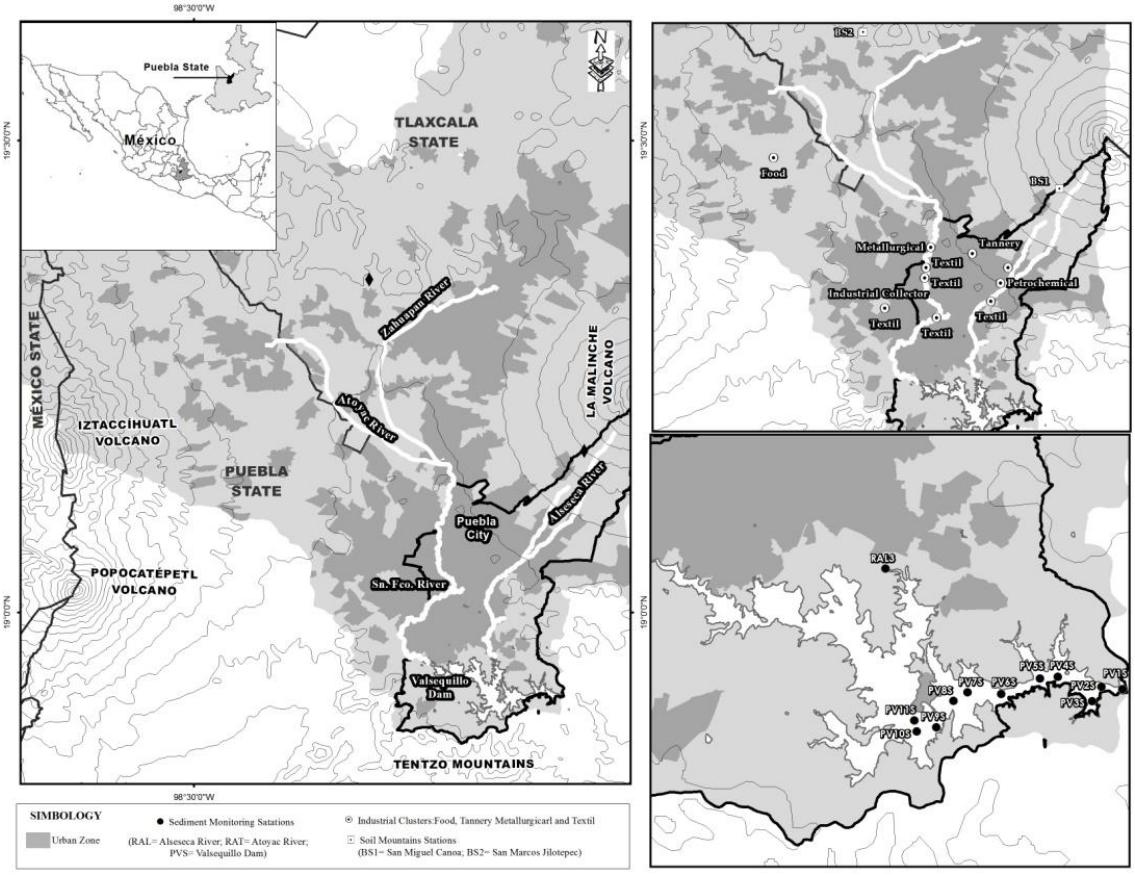
that descend from the slopes of the volcano La Malinche. The industrial development of the area is mainly focused on the areas like textile, chemical, building materials, electrical and automobiles.

The Valsequillo Dam has a storage capacity of 304 million m^3 and an area of approximately 3,000 ha. The water from the dam is used to irrigate agricultural fields in the downstream direction. The Atoyac river contributes 69 ton per day of pollutants, of which 8 tons correspond to Zahuapan River and 21.5 tons from San Francisco River, plus an additional 28 ton by Alseseca river and its tributaries. In total they generate a total of 97 ton per day, which are discharged into the Valsequillo dam, promoting a severe pollution problem.



Source: CIIEMAD - IPN.

Fig. 1: Study Area

2.2. Water and Sediment Sampling and Analysis

Eleven water and sediment samples in Valsequillo dam which is located in the south eastern side of Puebla City (Figure 1). Water samples were collected in polyethylene containers and were preserved with HNO_3 until further analysis. The sediment samples were collected with a grab sampler which took about 300 to 500 g of sediment at the bottom of the dam and were stored tightly in polyethylene bags which were labeled and refrigerated subsequently at 4 ℃ until analysis.

The extraction of metals from the samples obtained was done by acid digestion method closed using autoclave system, recently developed by Navarrete-Lopez et al (2012) [12]. The metals analysis was performed by Atomic Emission Spectroscopy with Inductively Coupled Argon Plasma (ICP-AES). Standardized methods were used throughout the analysis and Standard Reference Materials (SRMs) were used to ensure reproducibility and accuracy of the procedure. The analysis were done for As, Cd, Cu, Cr, Ni, Pb and Zn in 11 surface water and sediment samples collected from Valsequillo Dam during August 2009.

3. Results and Discussion

3.1. Concentration Pattern of Trace Metals in Water and Sediment Samples

The results of concentration pattern are presented in $mg.L^{-1}$ for water samples and $mg.kg^{-1}$ for sediment samples. The minimum, maximum and mean values are showed in Table 1.

Table 1: Minimum, Maximum and Mean Concentration Values in water ($mg.L^{-1}$) and sediment ($mg.kg^{-1}$) samples in Valsequillo dam

Values	As		Cd		Cr		Cu		Ni		Pb		Zn	
	W	S	W	S	W	S	W	S	W	S	W	S	W	S
Minimum	2.9	0.02	< 13	7.33	< 3	43	< 13	21	< 17	27	< 15	3.9	< 20	56
Maximum	82.5	3.48	< 13	10.63	4.7	77	< 13	47	< 17	50	41.9	33.3	36.5	133
Mean	**18**	**1.90**	**< 13**	**8.73**	**-**	**60**	**< 13**	**35**	**< 17**	**40**	**-**	**16**	**-**	**97**

W = Water, S=Sediment, Values concentration in ppm

The concentration pattern of As, Cd, Cr, Cu, Ni, Pb and Zn in the water and sediments of the Valsequillo Dam can be seen in Figure 2A-2B. As mentioned above the water of the rivers Alseseca and Atoyac is directly discharged into Valsequillo dam. In Figure 2A-2B, the left hand side shows that the average concentration of each metal, in water and sediment, before entering the dam. In the case of water, the concentrations of the 7 elements in rivers is higher than in the dam, while it is on the opposite case and is less sediment in rivers and higher in the dam.

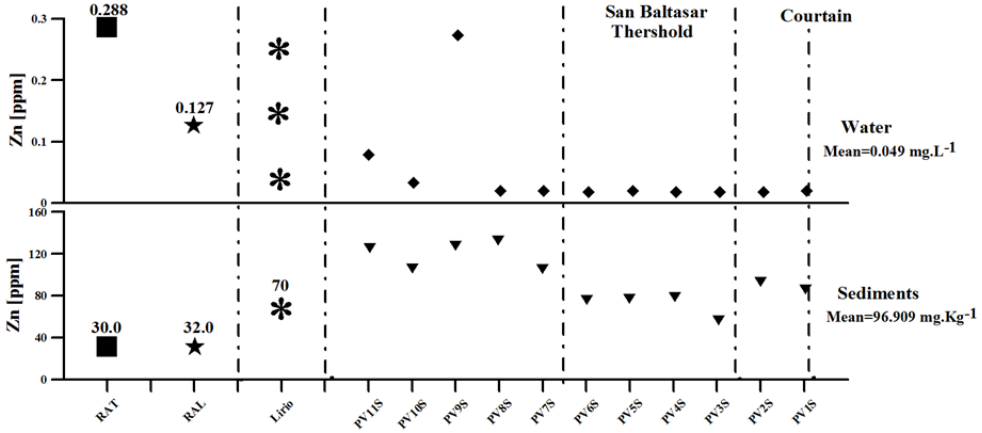


Fig. 2A: Concentration pattern of Zn in water and sediments of the Valsequillo Dam

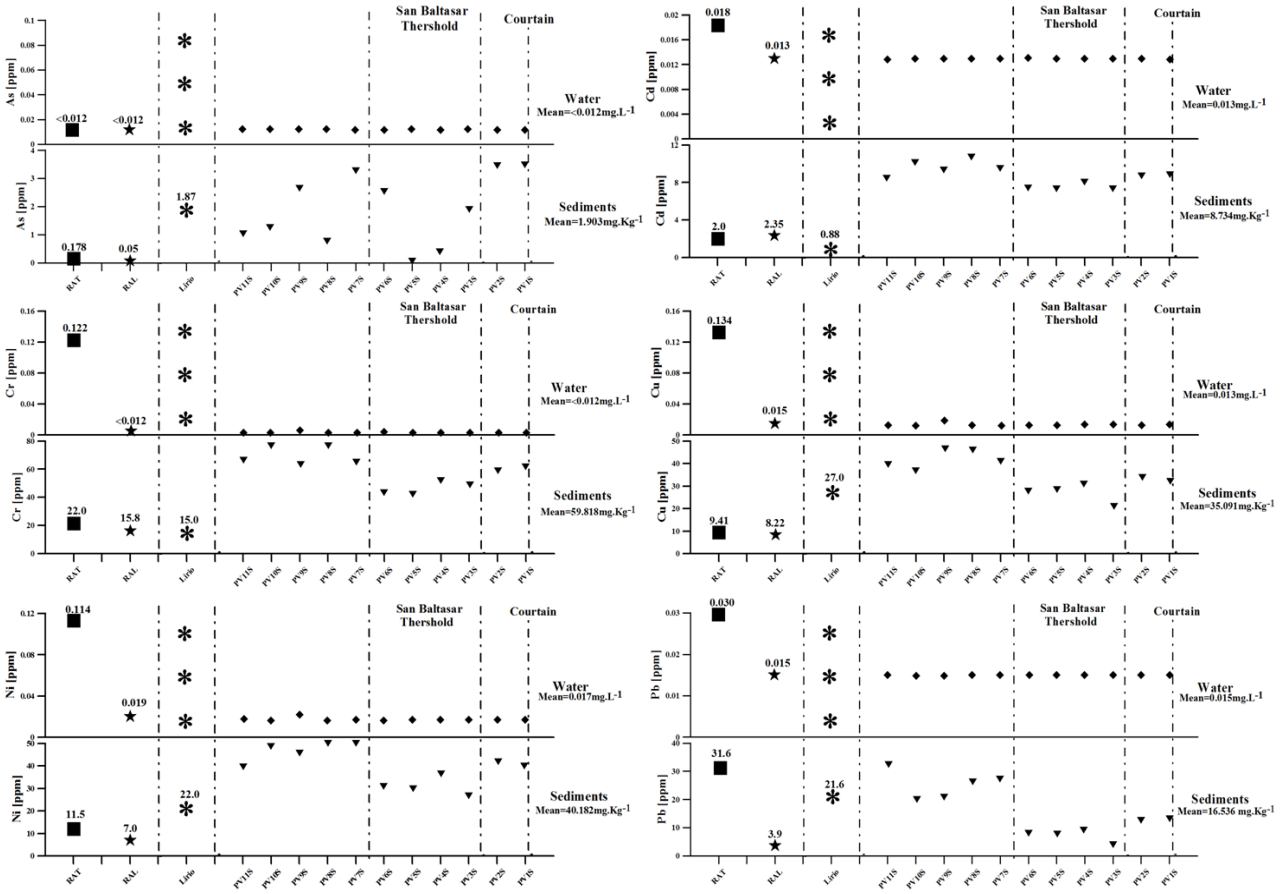


Fig. 2B: Concentration pattern of As, Cd, Cr, Cu, Ni and Pb in water and sediments of the Valsequillo Dam

3.2. Geoaccumulation Index in Sediment Samples

The Igeo indexing approach was used to quantify the degree of anthropogenic contamination in soils and sediment an to compare the different elements. The I_{geo} for each element was calculated using the following formula: $I_{geo} = \log_2 [(C_n/1.5) \times B_n)]$, where I_{geo} is geoaccumulation index, C_n is measured element concentration in soil or sediment sample, and B_n is the geochemical background value. The I_{geo}: < 0 = Class 1 = Unpolluted; > 0-1= Class 2 = Unpolluted to moderately polluted; > 1-2= Class 3= Moderately polluted; > 2-3= Class 4= Moderately to strongly polluted; > 3-4= Class 5= Strongly polluted; > 4-5= Class 6= Strongly to very strongly polluted; and > 5= Class 7= Very strongly polluted [13]. Calculation results of geoaccumulation Index (I_{geo}) are shown in Figure 3 and they indicate that the sediment quality in Valsequillo dam is moderately contaminated for Cu; moderately to heavily contaminated by Pb and As.

3.3. Sediment Quality Guide USEPA (Environmental Protection Agency of the United States of America)

According to the Sediment Quality Guide of USEPA the sediment of Valsequillo dam is moderately contaminated for As, Cd, Cu, Ni, Pb, Zn and only Cr is within the values.

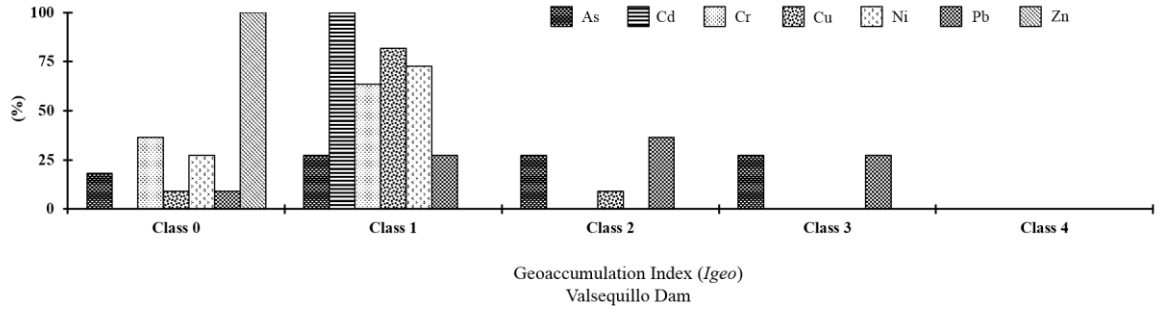


Fig. 3: Geoaccumulation Index (Igeo) results in sediment of Valsequillo Dam

4. Discussion

The concentration values of As, Cd, Cr, Cu, Pb and As in water of Valsequillo dam are within the estimated intervals for water of rivers according to Gaillardet et al., 2003 [As (0.11 - 9.4 $\mu g.L^{-1}$), Cd (10 - 100 $\mu g.L^{-1}$), Cr (0.3 – 2.1 $\mu g.L^{-1}$), Cu (0.27 -3.53 $\mu g.L^{-1}$), Pb (0.007 - 3.8 $\mu g.L^{-1}$), Ni (0.15 - 10.39 $\mu g.L^{-1}$) and Zn (3.3 - 10.3 $\mu g.L^{-1}$)]. However, the concentration of some elements is high in sediment and it is clearly observed in I_{geo} indicating that they are moderately contaminated for Cu and moderately to heavily contaminate by Pb and As.

5. Conclusions

The results from the present study indicate that Valsequillo Dam has serious problems related to enrichment of metals which is mainly due to the contributions of urban waste and industrial discharges through Atoyac, Alseseca rivers, as well as discharges from the nearby habitats close to the reservoir. In the aquatic layer, the Valsequillo Dam contains virtually no detectable concentrations for the 7 elements, although As, Cr, Pb and Zn showed significantly higher concentrations at one or two locations. In sediments, the higher concentration of toxic elements clearly suggests that the metals clearly precipitate in different chemical forms, mainly in the form of hydroxides, sulphates, carbonates, phosphates. However, the water hyacinths in the region help in absorbing the metals which enter the dam site to reduce the enrichment.

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