Metal contamination of a riparian area in the Conchos watershed of Chihuahua, Mexico

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Abstract

This study investigated metal contamination levels in soils at six points along a riparian area of the Conchos watershed in Chihuahua, Mexico. Soil samples were collected from the surface horizon (0-15 cm) as well as from two subsurface horizons (15-30 cm and 30-50 cm). Cadmium, sodium, manganese, lead, copper, iron and zinc concentrations were determined by flame atomic absorption spectrometry while arsenic and mercury concentrations were calculated by hydrourous-generator atomic absorption spectrometry. Also measured were pH, M.O.(%), $CaCO_3$(%), H.C., CE, N-NO_3 (as Kg ha^{-1}), P, and K. Arsenic values were higher in the Zaragoza point with the highest value of 2.3192 ppm in the upper soil horizon. Mercury, manganese, and sodium did not show a specific trend, however mercury concentrations ranged from 0.2381 to 1.2715 ppm and were higher than those values that were present in a typical soil (0.03 to 0.2 mg kg^{-1}). Cadmium levels were less than 9 ppm in all samples. Lead and zinc concentrations were higher in the site near an urban center reaching values of 36.8 ppm and 68.8 ppm, respectively, in the 0-15 cm horizon. The pH ranged from 7.08 to7.70. This study showed that soils in the riparian areas of one of the most important watersheds in northern Mexico are above desirable levels.
Keywords: riparian soils, metal contamination, Conchos watershed, Chihuahua, Mexico.

1 Introduction

Riparian areas are located adjacent to streams, lakes, or surface waters where wildlife can find diverse food, water, and cover. In the particular case of Chihuahua, Mexico, the boundary of the riparian areas is not clearly defined; therefore, at some points this area might be considered as large as 5 m wide and in other points as large as 50 m or more. Despite the heftiness of the riparian area, it plays an important role in terms of physical, biological, and ecological function and; in addition, it has important social benefits.

The Rio Conchos and its main tributaries have been dammed, ditched, and drained throughout its flow, due in part, to the pressure of about one million human inhabitants demanding more water. These actions in synergy with the increased erosion provoked by the widespread land clearing at the forest area of the watershed, overgrazing and other processes, have decreased stream flow, contaminated water (Rubio et al., [15]; Kelly, [9]; Gutierrez and Borrego, [7]) and increased the sediment content. In consequence, the side of the river channel is narrow and has less capacity to absorb water. These changes have harmed the wildlife of the watershed, in particular, those visiting species that need adequate clean drinking water as well as those species that live in the riparian habitat.

Perhaps most detrimental to the whole riparian ecosystem is the discharge of human waste from human communities established along the stream, the unreasonable dumping of industrial wastes, some residues of the different agriculture production systems, and in general, the miscellaneous sort of contaminants that get into a river. Although some sediments can be removed from riparian areas (Daniels and Gilliam, [6]) as well as some nutrients like N, P, Ca, K, S, and Mg (Lowrance et al., [11, 12]), the actions of the metals and other contaminants is not clear (Hupp et al., [8]). The question that arises as a consequence is: has the soil of the riparian area along the Río Conchos become contaminated?

This paper represents a first attempt to answer that question. This is important because heavy metals are not biodegradable and mostly immobile (Mermut et al., 1996); therefore they tend to accumulate in soils. The objective of this study was to determine the metal contamination levels in the soils at six points along a riparian area of the Conchos watershed in Chihuahua, Mexico. It was hoped that this study would shed light on the levels of contaminants in the riparian area that contribute to vegetation diversity (Thomas et al., [16]) and allowing richness of species (Cotter, [4]) besides other benefits.

2 Materials and methods

Six points along the Rio Conchos watershed were selected for soil analysis. Point 1 was located along the Rio Chuviscar (latitude 28° 49’ 23.7”; longitude 105° 54’ 57.0”; 1,279 masl) about 15 km below the city of Chihuahua, which has a population of 750,000. Point 2 was located along the Rio San Pedro (latitude 27° 57’ 13.2”; longitude 106° 06’ 35.9”; 1,375 masl) approximately 5 km below the municipality called Satevo. Sampling point 3 was along the Rio Conchos near the municipality called Valle de Zaragoza (latitude 27° 28' 15.5"; longitude 105° 42' 25.4"; 1,329 masl). Point 4 was located along the Rio Parral (latitude 27° 40' 03.4"; longitude 105° 12' 33.8"; 1,228 masl) about 30 km below the city of Parral, which has a population of about 100,000 inhabitants and mining operations. Point 5 was located along the Rio Florido (latitude 27° 40' 36.6"; longitude 105° 08' 37.4"; 1,225 masl). Point 6 was located near the city of Ojinaga (latitude 29° 34' 02.1"; longitude 104° 26' 46.1"; 786 masl) about 3 km above the junction with the Rio Bravo/Rio Grande. These sites will be referred as sites Chuviscar, San Pedro, Zaragoza, Rio Parral, Rio Florido and Ojinaga as they were mentioned.

In each point a perpendicular imaginary line was draw along the river's edge for both sides of the river. Soil samples were randomly taken at depths of 0-15 cm, 15-30 cm and 30-45 cm at each side of the riparian area of the river. Then the soil samples were mixed to produce a composite sample for each depth at the side of the river. Therefore, three soil samples were obtained for each side of the river giving six soil samples per sampling point, and a total of 18 soil samples.

Cadmium (Cd), sodium (Na), manganese (Mn), lead (Pb), copper (Cu), Iron (Fe) and zinc (Zn) concentrations were determined by flame atomic absorption spectrometry while arsenic (As) and mercury (Hg) concentrations were calculated by hydrourous-generator atomic absorption spectrometry. Also measured were pH, M.O.(%), CaCO3(%), H.C., CE, N-NO3 (as Kg ha-1), P, K and Ca. A complete factorial 2x3 arrangement was used. The triple interaction was considered as the error, to prove the other effects. An analysis of variance (ANOVA) was performed for each variable considering six sampling points, two riparian profiles (left and right) and three soil sampling depths. Differences were noted at the 0.05 level of significance.

Table 1: The ANOVA of the riparian soil in the Conchos watershed, Mexico.

Source	pH	MO	$CaCO_3$	HC	EC	P	K
Model F value	4.20*	5.26*	8.84*	3.03*	11.64*	5.06*	6.19*
Site	12.35*	15.26*	26.27*	4.33*	36.82*	16.31*	14.83*
Profile	3.24	0.12	5.83*	7.59*	2.36	7.69*	1.06
depth	0.17	7.81*	1.60	1.87	0.49	0.64	6.93*
Site x depth	1.03	0.26	1.87	2.15	2.21	0.05	2.23

*Significant differences using 0.05 level

3 Results and discussion

The ANOVA analysis showed significant differences for the variables pH, MO, CaCO3, HC, CE, P, and K but no significant differences were noted for N-NO3 (Table 1). A higher pH value (7.55) was noted for the Rio Florido site, while a lower pH (7.19) was observed in the San Pedro. The MO and K were different for site and depths effect. The high amount of MO was noted in Chuviscar with 1.46% in comparison with Ojinaga where it was 0.39%. Potassium levels as high as 425 ppm were found along the San Pedro while lower levels were noted along Ojinaga with 215 ppm. The variables CaCO3, HC, and P were different for site and profile. No significant interaction was noted for any of these variables. The EC was highest for Ojinaga with 2.2500, while levels of 0.3866 were noted for the San Pedro. These variables are important because of the uptake and bioaccumulation of metals by plants, which are dependent on these factors (Chlopecka et al., [5]).

Cadmium levels were not detected in any soil samples, while the levels of Cu, Fe and Na were not significantly different (Table 2). There was a Cu overall mean of 1.12 ppm, 5.14 ppm for Fe and 906.16 ppm for Na. Sodium levels were highest in Ojinaga with 1,065 ppm in comparison with 626 ppm detected at San Pedro. The amount of arsenic in soils was significantly different among sites. The overall arsenic mean was 1.74 ppm. The Zaragoza site had higher As amounts with 2.19 ppm while the Rio Florido site had 1.28 ppm. According to Bowie and Thornton [2], a typical soil contains 5-40 mg kg-1 of As; therefore, the soils tested in this study should be classified as typical soils with regards to As concentrations. Manganese levels did not show a specific trend, although Mn values were different for site effect. The overall mean for Mn was 369.94 ppm.

The ANOVA analysis showed significant differences in the amount of Hg (Table 2). The Hg concentrations ranged from 0.46 ppm observed at the Chuviscar site to 0.95 ppm detected at the Parral site. It should be noted that even the lower amount of Hg was higher than values that are present in a typical soil, which ranges from 0.03 to 0.20 mg kg-1 (Bryan and Langston [3]; Licheng and Kezhun, [10]). There were noted differences in site, depth, and the interaction site x depth. The overall mean was 0.67 ppm. The capability of Hg to alloy with gold has been recognized for thousands of years. This process permits the recovery of gold as an amalgam, but the Hg becomes a potential contaminate. The Parral area has been intensively exploited for hundred years by gold mining and the applications of Hg for obtaining gold may be an explanation for the high levels of Hg in the Parral area.

The Zn accumulation in soil was different among sites and depth. The highest amount of Zn was observed at Ojinaga with levels of 74.05 ppm in the 0-15 cm depth, 67.05 ppm in the 15-30 cm depth and 64.45 ppm in the 30-45 cm depth. The lowest amount of Zn was noted in Rio Florido with a mean of 40.15 ppm; however, it is important to point out that Zn accumulation was found in the upper part of the soil profile (Figure 1). This trend was noted in the six observed sites. Birch (2004) found levels as high as 343 mg kg-1 in a highly urbanized soil. With respect to lead concentrations, it was different in site and profile. The highest amount of Pb was found at Ojinaga with 36.71 ppm in comparison with the lowest amount observed at the San Pedro site with 18.00 ppm. It should be pointed out that Pb and Zn amounts were highest at the site near the urban center (Ojinaga site).

Table 2: Some ANOVA results for the metals tested in a riparian soil in the Conchos watershed, Mexico.

Element	DF	Sum of squares	Mean square	F value	Pr>F
Cu	18	19.7535	1.0974	0.94	0.5564
Fe	18	237.33	13.18	1.62	0.1639
Na	18	274968.00	30552.00	1.49	0.2934
Mn	18	168661.63	1874.18	7.46	0.0047
As	18	3.8689	0.21	2.02	0.0764
Hg	18	2.2192	0.12	5.99	0.0003
Pb	18	1970.83	109.49	11.53	<.0001
Zn	18	5016.54	278.69	8.78	<.0001

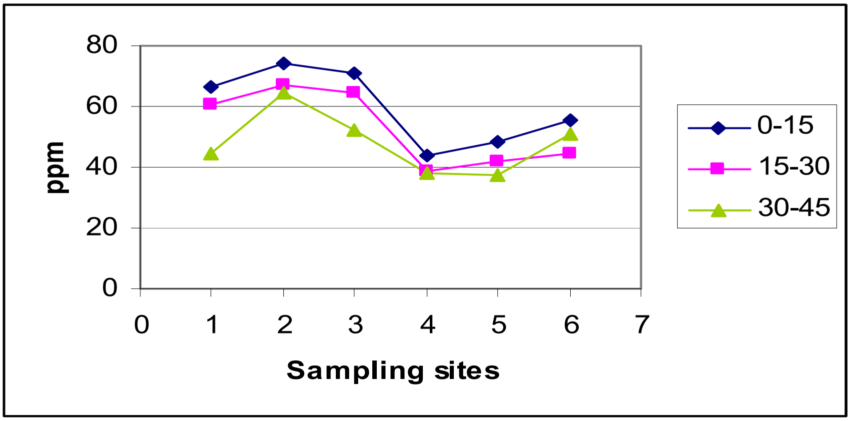

Figure 1: Zinc accumulation in three soil depths in six sampling points.

4 Conclusion

This study showed that soils in the riparian areas of one of the most important watersheds in northern Mexico are not contaminated with some elements. Nevertheless, the presence of high levels of mercury in the six sampled points of the riparian area must be of great concern. This is important because Hg has been included as one of the priority dangerous substances (MINDEC, [14]).

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