Journal of Environmental Biology
ISSN : 0254-8704

J.Environ.Biol.
23(4), 347-352 (2002)

Soil arsenic contamination in the Cape Region, B.C.S., Mexico.

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(Received : 19 November, 2001 ; Accepted : 10 February, 2002)

Abstract *: We evaluated the content of arsenic in soils of an abandoned mining zone in the Cape Region, B.C.S. During June to August 1997, we were in the field sampling these soils. The concentration of arsenic was determined using the Chapman and Parket techniques. The results were statistically analyzed by ANOVA tests. Our results indicate that all the soils sampled in the region exceed the environmental limit (2 mg/K) established by Galvan and Corey (1987). According to the data found the more probable cause of this soil arsenic contamination is the rainy runoff.*

Key words *: Mining, Soil contamination, Arsenic in soils, Baja California sur, Mexico.*

Introduction

Soil is the major natural resource on which society depends for the production of food, feed, fiber, and wood products (Sancha and Castro, 2000). Human activities and natural forces have reduced soil productivity and damaged adjacent ecosystems (Traina and Laperche, 1999). Industrial activities and improper use of municipal and industrial byproducts and animal manures can build up nutrients and toxic trace elements in soils (Sancha and Castro, 2000).

Because mining eventually extracts all the profitable resources, mines are abandoned and mining wastes are left on the surface of the soil. This is why some of the largest and most complicated deposits of hazardous waste are at mining sites. Mining directly disturbs about 240,000 km^2 of the earth's surface (Salomons, 1988), an area about the size of state of Oregon.

In Mexico, mining has existed more than 400 years and contamination has existed since then, mainly affecting soils, landscapes, and groundwater (Ruiz Mendez, 1999). It is estimated there are about 10,000 to 50,000 abandoned mines in Mexico (Carillo and Huyck, 1997). In Baja California Sur, in the San Antonio-El Triunfo mining district in Cape Region (Fig. 1), there gold and silver have been mined since the XIX century (Martinez, 1997). Mining in this region ended in 1940. There were left thousands of tons of waste on the soil surface (Gonzalez, 1995).

At present, there has been no quantification of the contamination levels in the soils of the region. For this reason we did this study.

Materials and Methods

Study site : Field work was done in the San Antonio-El Triunfo mining district in the southern part of Baja California Sur, Mexico (Fig. 1) ($23^0$48' to $23^0$49'N; $110^0$06' to $110^0$03'W) and at a control site at El Comitan in the northern part of the Cape Region, 20 km north of La Paz, Baja California Sur, Mexico ($24^0$10'N; $110^0$30'W).

The area of San Antonio-El Triunfo is geologically situated on the central part of the San Lucas tectonic block. Physiographically, it is from sea level to 1000 m with muddy-sandy soils. The climate is warm-arid with an average annual temperature of 22.1^0C and maximum precipitation of 156 mm falling primarily during summer

(Arriaga and Ortega, 1988). Its predominant flora is xerophytic scrub (Leon *et al.*, 1988).

From June to August 1997 we developed three periods of fieldwork to sample soils in different sites in the surround of towns of San Antonio and El Triunfo.

Edaphic profiles made at the four cardinal points around each well in both towns inside a 50 m radius. We took 250 g samples at each point at 0-15, 15-30, and 30-45 cm depth. The samples obtained at the same depth (4) were mixed and homogenized to yield a sample at each depth.

The samples were taken in a plastic shovel and kept in plastic bags labeled with the site of extraction. In the laboratory the material was shifted through a 2 mm sieve for physical

Table – 1 : Physical and chemical properties of the sampled soils.

Profile (pit)	Sample #	Depth (cm)	Dry color	Wet color	Saturation %	Porosity %	Texture	pH	T °C	Electric conductivity (Siemens)	[As] (mg/kg)
1	1, 2	0-15	10 YR4/2	10 YR3/2	26	37	SM	7.81	22.1	2.03	14.69
	3, 4	15-30	10 YR4/2	10 YR3/2	25	36	SM	7.81	22	2.05	16.12
	5, 6	30-45	10 YR4/2	10 YR3/2	26	37	SM	7.80	22.1	2.05	19.34
2	7, 8	0-15	10 YR4/2	10 YR3/2	36.6	38	SM	7.22	22.4	2.21	12.39
	9, 10	15-30	10 YR4/2	10 YR3/2	36.6	42	S	7.20	22.4	2.22	8.50
	11, 12	30-45	10 YR4/2	10 YR3/2	36.6	36	SM	7.23	22.4	2.22	4.22
3	13, 14	0-15	10 YR4/2	10 YR3/2	35	33	SM	6.90	23	2.06	19.93
	15, 16	15-30	10 YR4/2	10 YR3/2	34	37	SC	6.91	23.4	2.07	20.86
	17, 18	30-45	10 YR4/2	10 YR3/2	36	35	SM	6.91	23.4	2.07	18.17
4	19, 20	0-15	7.5 YR6/6	10 YR4/4	27.6	44	S	7.80	22	3.33	16.46
	21, 22	15-30	7.5 YR6/6	10 YR4/4	27.6	42	S	7.81	22.4	3.36	13.08
	23, 24	30-45	7.5 YR6/6	10 YR4/4	27.6	45	S	7.83	22.5	3.33	14.94
5	25, 26	0-15	5 YR4/3	5 YR3/3	34	31	MS	7.91	22.2	2.15	13.83
	27, 28	15-30	5 YR4/3	5 YR3/3	34	32	MS	7.85	22.3	2.05	8.51
	29, 30	30-45	5 YR4/3	5 YR3/3	34	32	MS	7.93	22.3	2.05	5.54
6	31, 32	0-15	7.5 YR6.5	10 YR4/4	22.3	42	S	7.17	23.4	2.03	5.60
	33, 34	15-30	7.5 YR6.5	10 YR4/4	22.3	41	S	7.17	23.5	2.07	5.78
	35, 36	30-45	7.5 YR6.5	10 YR4/4	22.3	42	S	7.20	23.6	2.07	6.40
7	37, 38	0-15	5 YR5/4	5 YR3/3	36	37	SC	7.22	21.4	1.41	7.08
	39, 40	15-30	5 YR5/4	5 YR3/3	36	36	SC	7.22	21.4	1.44	9.94
	41, 42	30-45	5 YR5/4	5 YR3/3	36	36	SC	7.22	21.4	1.41	8.00
8	43, 44	0-15	5 YR5/4	5 YR3/3	39	33	SC	7.24	21.2	1.6	8.02
	45, 46	15-30	5 YR5/4	5 YR3/3	39	35	SC	7.24	21.2	1.6	11.18
	47, 48	30-45	5 YR5/4	5 YR3/3	39	35	SC	7.24	21.0	1.61	7.40
9	49, 50	0-15	10 YR5/3	10 YR4/2	35	31	MS	7.16	22	2.2	0.58
	51, 52	15-30	10 YR5/3	10 YR4/2	35	34	MS	7.16	22.1	2.2	0.49
	53, 54	30-45	10 YR5/3	10 YR4/2	35	41	S	7.14	22	2	0.55

Note :

10 YR3/2 Dark brown;
10 YR4/2 Dark grayish-brown
10 YR4/4 Dark yellowish brown
10 YR5/3 Brown
7.5 YR6.5 Light brown
7.5 YR6/6 Light brown
5 YR3/3 Dark reddish brown
5 YR4/3 Dark reddish brown
5 YR5/4 Yellowish-red

S. Sand
S.M. Sand-marrow
M.S. Marrow-sand
S.C. Sand-clay

determinations (color, saturation percentage, porosity, texture, and reaction with HCl), and another sieve (0.85 mm) for the chemical determination (pH and conductivity) (Escoppinichi *et al.*, 1991). The sieved samples were divided and digested in triplicate in 1 mL of acetic acid and 3 mL of deionized water in Teflon bombs at 70°C for the determination of the bioavailable arsenic fraction by the methods of Agemian and Chau (1976) and Luoma and Moore (2000). For the analysis of the extracts of the digestions, and atomic absorption spectrometer (Spectronic Genesys mod 200A) was used.

To find statistical differences among the samples, arsenic results were compared by ANOVA (Sokal and Rohlf, 1969) followed by the Turkey-Kramer test (Sokal and Rohlf, 1969)

Results and Discussion

Obtained samples (54) were taken from the soil of nine (9) pits or profiles. The data on soil pH, temperature, electrical conductivity, texture, percentage of saturation, percentage of porosity, dry and wet color, and arsenic concentration are shown in Table 1. The soils were neutral (pH 6.9-7.9). The percentage of saturation varied from 22% to 39%, and the porosity percentage from 31% to 45%. The fraction of bioavailable arsenic varied from 0.46 mg/kg at the control site to 20.86 mg/kg.

Table – 2 : Means of AS bio-available fraction by edafologic profile (pit).

Edafologic profile	Town	Location	Arsenic, bioavailable fraction (mg/kg)	Homogeneous group
1	San Antonio	23°47'47" N 110°03'20" W	15.77	d
2	San Antonio	23°47'14" N 110°03'20" W	11.41	b
3	San Antonio	23°47'11" N 110°03'27" W	17.31	d
4	San Antonio	23°47'11" N 110°03'20" W	14.82	c
5	San Antonio	23°48'50" N 110°03'10" W	9.84	b
6	San Antonio	23°48'51" N 110°03'10" W	6.02	b
7	EL Triunfo	23°48'02" N 110°06'22" W	8.64	b
8	EL Triunfo	23°48'03" N 110°06'22" W	9.03	b
9	EI Comitan	23°08'10" N 110°26'30" W	0.46	a (control sample)

Note : The environmental limit for arsenic is 2 mg/kg (Galvan and Corey, 1987).

The results indicate that considerable quantities of bioavailable arsenic are in the samples obtained in San Antonio and EI Triunfo. All of them surpass the environmental limit of Galvan and Corey in 1987 (2 mg/kg). In EI Comitan (control site), the average value was inside the environmental limit.

The major arsenic concentration was found at 15-30 cm from profile 3 from San Antonio (20.86 mg/kg), and the least concentration

at 15-30 cm at profile 9 from EI Comitan (0.46 mg/kg) (Fig. 2). There were no statistical differences significative between the depths ($F_{(2,51)}$=0.26; P<0.77) and the test for homogeneity revealed only one group.

There were significant differences in arsenic concentration among all pit profiles analyzed ($F_{(8,45)}$=21.16; P<0.0001) (Table 2). There are differences between the soils of towns ($F_{(2,51)}$=15.21; P<0.0001), with San Antonio with

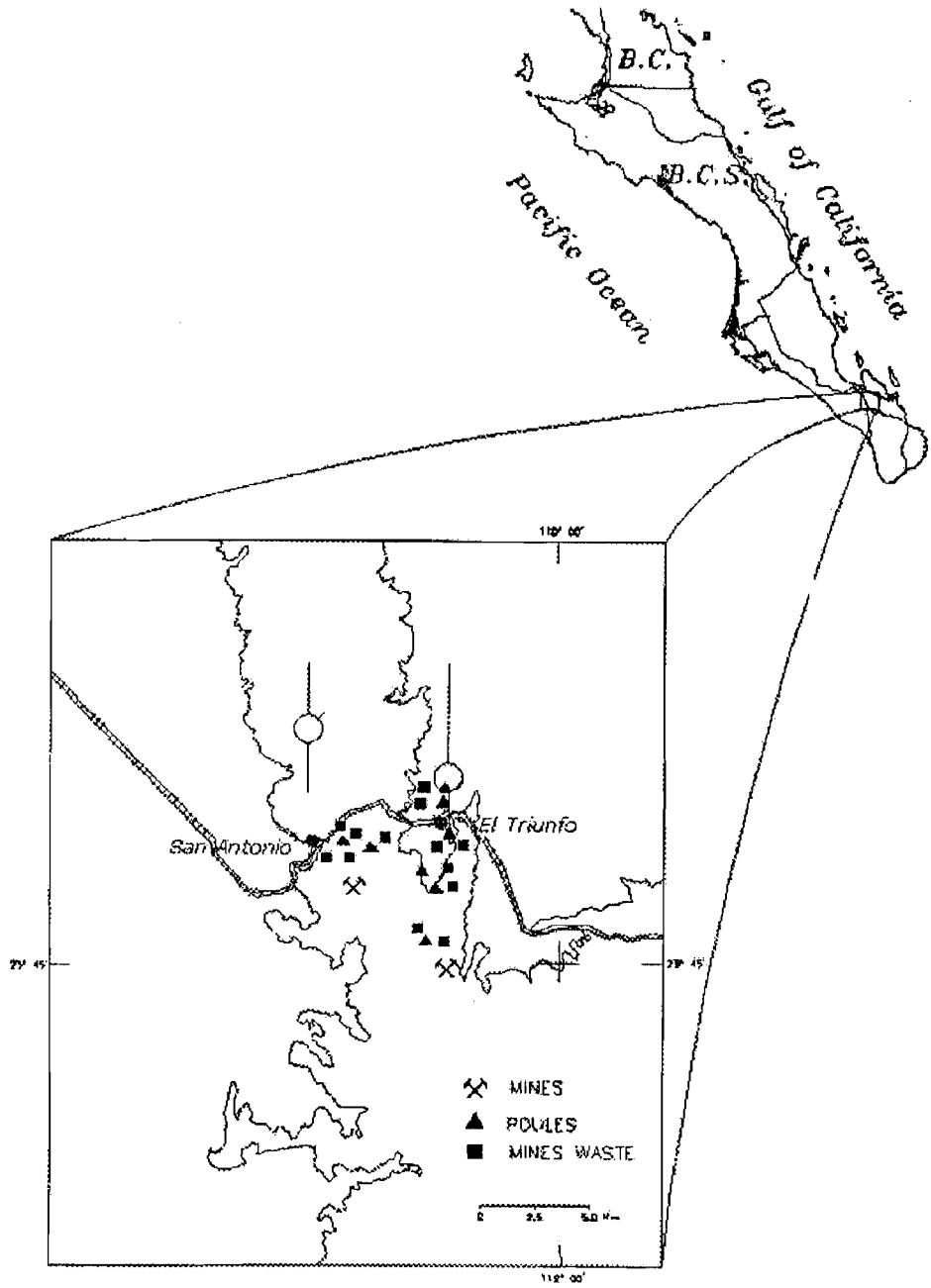

Fig. 1. Study site. Location of the mines waste ■ and pits ▲.

the greatest arsenic concentration (x^2=12.46 mg/kg) than EI Triunfo (x^2=8.68 mg/kg).

Table 2 shows four groups. Profile number 9 (control sample) with low values was

significantly different from groups b, c and d. The profiles of group b (profiles 2, 5, 6, 7, and 8) were statistically similar with intermediates values (6-11.41 mg/kg). Group c (profile 4) has high values of arsenic (14.82 mg/kg); group d (profile 1 and 3) has the greatest concentration of arsenic (15.77-17.31 mg/kg).

San Antonio has a greater average arsenic concentration. This is attributed to the presence of the mine San Junes, which is more recent than the other mines in the adjacent town of El Triunfo.

There are various factors or patterns that could determine the arsenic distribution in the soil; the age of the ore waste, the precipitation, and the wind. Carillo and Huyck (1997) observed that the wind plays an important role for dispersion of the arsenic in the area.

Gough *et al.* (1979) made a comparison among the fractions of bioavailable arsenic at 3 depths (0-15, 15-30, and 30-45 cm) of the soils of the Yakima valley in USA and found a larger concentration of soluble arsenic in the first 15 centimeters depth. But in this case, the concentration is not correlated with the deep.

Because the dominant winds of the region flows from south to north, if the arsenic contamination could be produced by eolic factors, we must expect that the sample points 3, 4, 7 and 8 showed similar values. This is not the case.

Another cause of this arsenic contamination could be attributed to the combined effect among the altitude of the sample sites and the distance and altitude of the mining waste. As we can see in Fig. 1 sample sites 7 and 8 are closer

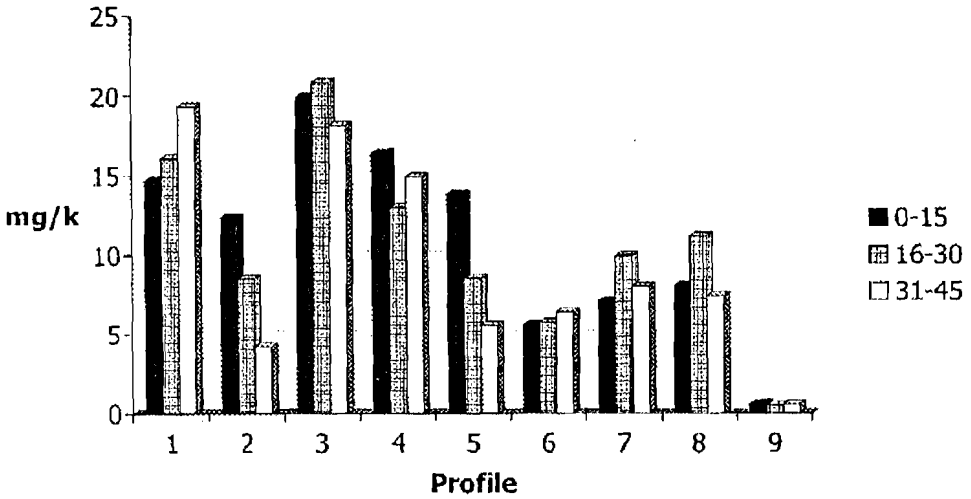

Fig. 2. Concentration of arsenic bioavailable by deep in soil.

to the mining waste but are located at the same level. This is not the case for the sample sites with the highest soil arsenic values found; 3 and 4; these sample sites despite that are located far from the mining waste, are the ones with the lowest level location. Suggesting that rainy runnof is the most probable cause of soil arsenic contamination in this region

There are high levels of available arsenic in the soils of the mining district San Antonio-El Triunfo surpassing the established limit (2 mg/kg), which is the product of mining in the area. This is the first study of arsenic soil contamination at this site in Mexico.

Acknowledgements

This study was supported by the Centro de Investigaciones Biologicas del Noroeste and the Consejo Nacional de Ciencia y Technologia of

Mexico. Thanks to Elis Glazier for editing the English-language text.

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