Geochemical characteristic of the Acoculco geothermal soils

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1) Objective

A geochemical approach has been applied to study the soils from Acoculco geothermal area (255 km^2). The aim was to evaluate the behaviour and distribution patterns of some PHE (Potential Harmful Elements) that could be hazardous for the local environment, farming activities and population.

2) Methodological Approach

On behalf of the Gemex project, 60 horizons from 18 soils were collected. Chemical analyses were performed by CICESE* and Certified Reference Material were used for quality check.

Data have been discussed taking into account the particular condition of this geothermal area, the typical levels for soils developed in similar geological conditions and the representative values for worldwide soils (Table 1 and 2).

	As	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn	References
Upper Continental Crust	2.0	.10	11.6	35	14.3	.056	18.6	17	52	Wedepohl,1995
Upper Continental Crust	4.8	.09	17.3	92	28	.050	47	17	67	Rudnick & Gao, 2003
World soils		.10		61	23		27	26	74	Li, 2000
European soils		.79		53	19.5		27	39	68	Angelone & Bini, 1992
World soils		.30		200	20		40	10	50	Angelone & Bini, 1992
World soils	4.7	1.10	6.9	42	14	.10	18	25	62	Kabata-Pendias Mukherjee, 2007
World soils	6.0	.35	8.0	70	30	.06	50	35	90	Adriano, 2001
Excessive levels in soils		5.0		100	100		100	200	250	Kabata-Pendias, 2000
Pre-industrial levels		.55		48	34		40	22		Callender, 2003

Table 1. Indicative levels of some PHEs in world soils.

MERCURY	mg/kg	References
Long Valley (California, USA)	.100 - 1.90	Klusman and Landres, 1978
Puna, Haway islands	.015 - 1.13	Cox, 1981
Sulawesi, Indonesia	.040 - .30	Suryantini, 2013
Tuscany	.020 - .30	Baldi, 1988
Mexicali, Mexico	.010 - .26	Pastrana-Corralet al., 2016
ARSENIC	**mg/kg**	**References**
Tibet, Cina	1.80 - 155 (mean 19)	Sheng et al., 2012
Kuala Selangor, Malaysia	up to 2478	Ashraf et al., 2011
Vinto, Geothermal area (Bolivia)	825 - 3390	Rotting et al., 2014

Table 2. Mercury and Arsenic levels in top soils from some geothermal areas.

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3) Descriptive Statistics

Considering the results summarized in Tables 3 and 4, data relating to minor and trace elements show, for some of them, a wide concentration range owing to the compositional heterogeneity which is typical of the geothermal areas. This applies mainly to S and As, while in the case of Mn can be related to the redox conditions' variability.

	Al	Ca	Fe	K	Mg	Na	P	S	Si	Ti	Zr
Samples Number	60	60	60	60	60	60	60	60	59	60	59
Min	2.86	.14	.77	0.43	.08	.10	.02	.01	20.6	0.40	.001
Max	10.8	5.72	9.51	2.24	0.63	1.05	.37	14.70	33.8	1.24	0.37
Mean	**7.79**	**0.99**	**4.59**	**1.34**	**0.20**	**0.54**	**0.10**	**1.69**	**26.8**	**0.78**	**0.17**
S.D.	1.43	.75	2.62	.43	.11	.21	0.06	3.41	2.9	.20	0.08
Median	7.98	1.03	3.67	1.30	.19	0.53	.10	0.19	26.4	.79	.17
C. Var	18.3	75.7	57.1	32.5	56.0	38.4	59.1	201	11.0	25.8	47.0

Table 3. Descriptive statistics for major elements in soils

	As	Ba	Cl	Cr	Mn	Ni	Rb	V	Zn
Samples Number	52	59	53	49	60	55	60	32	55
Min	.80	387	66.9	0.84	12.7	15.1	12.0	73.5	24.9
Max	2200	4200	251	96.2	3000	212	1200	238	180
Mean	**309**	**1420**	**140**	**56.25**	**401**	**73.13**	**141**	**152**	**111**
S.D.	498	881	37.8	22.4	558	43.8	159	44.8	47.1
Median	29.5	1200	137	54.5	136	71	110	156	122
C. Var	161	62	27	39.9	139	60	113	29.5	42.6

Table 4. Descriptive statistics for minor and trace elements in soils

The correlations show high "*r*" values especially for some pairs of elements associated with hydro-thermalism as As/S (*r=0.82*). Among the metals the greatest correlation is for Fe/V (*r=0.85*), Fe/Zn (*r=0.81*), V/Zn (*r=0.76*) and Fe/Zn (*r=0.80*). The correlation found between Ca and Zn (*r=0.75*) is the consequence of the ionic rays' similarity which leads them to participate in the same geochemical processes.

4) Principal Component Analysis

The PCA (Principal Component Analysis) evidences four groups (Figure 1):

- **Group A**: samples most enriched in Al, Fe, V, and Zn;
- **Group B**: samples with the highest concentrations of Ca, Mg and Mn;
- **Group C**: samples strongly influenced by geothermal activity (the presence As and S);
- **Group D**: samples widely dispersed in the PCA graph (includes soils with the highest concentrations of Na, K, Si, Ba, and Zr).

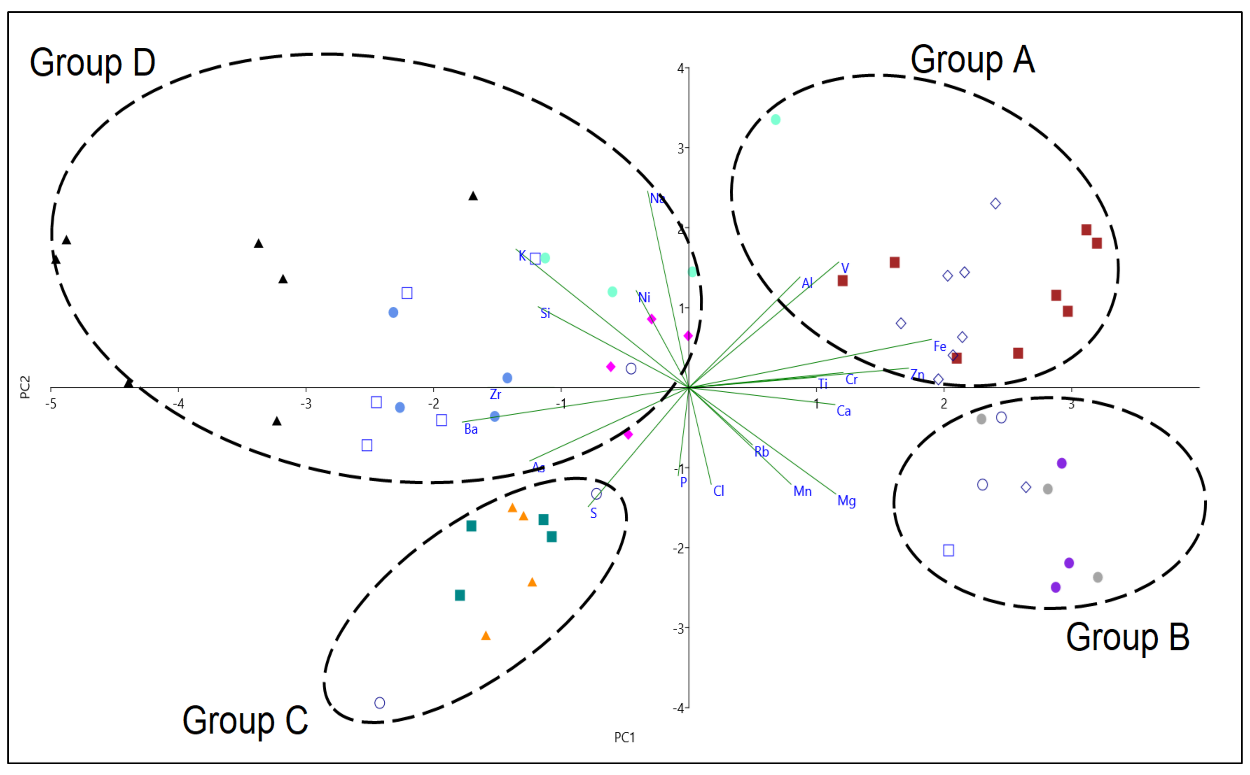

Figure 1. PCA for all Acoculco soil samples

5) Cluster Analysis

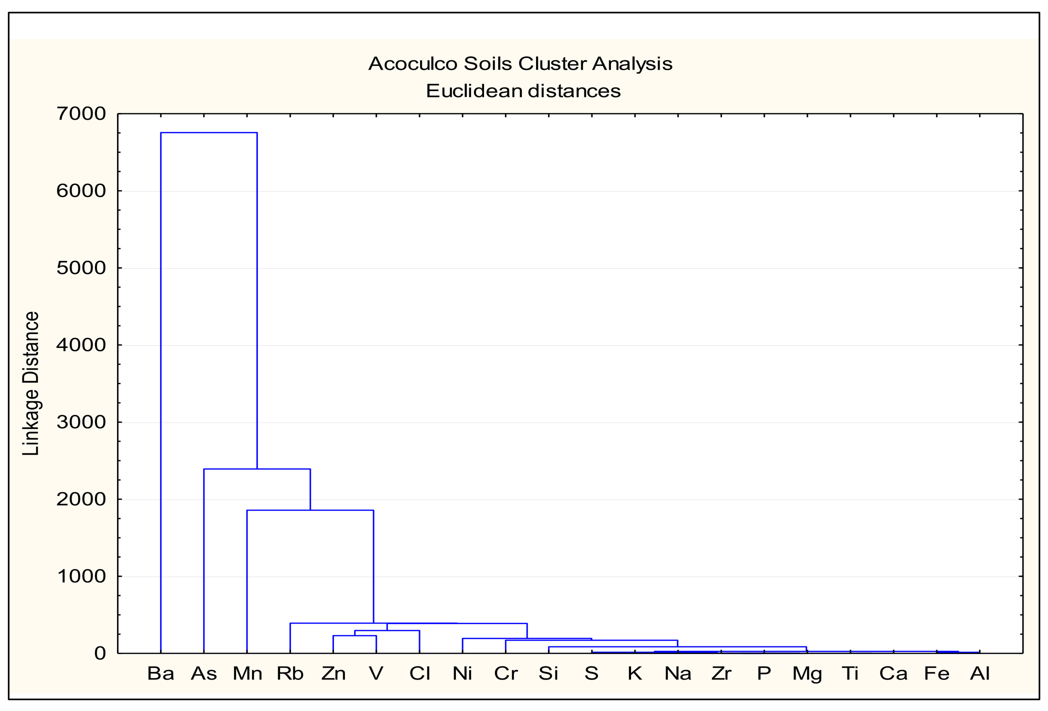

Figure 2. Cluster analysis applied to all soils for major and trace elements.

The Cluster Analysis (Figure 2) shows that Ba, and, to a lesser extent, also As, are the elements characterized by a marked distance compared to the other geochemical parameters. This probably depends on the Ba greater geochemical mobility triggered by the particular redox conditions.

6) Conclusion

The concentration levels for some trace elements do not show any particular concern. Arsenic is an exception (0.80-2200; mean 309 mg/kg), almost always above the typical values found in natural soils. Such levels may entail a hazard, in terms of its enrichment in local water and agriculture products. Among the heavy metals, Zn (mean 111 mg/kg) exceeds world natural soils typical values. Levels of attention also stand out for Ni (15.1-212; mean 73 mg/kg) and, to a lesser extent, for Cr (0.84-96; mean 56 mg/kg), since 200 and 100 mg/kg are respectively suggested, considering the data from world soils, as "excessive levels".

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