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A global, PCA analysis of physical-chemical characteristics and trace elements in farming soils irrigated with wastewater in Hidalgo, Mexico.

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ABSTRACT. The objective of this work was to evaluate the accumulation and distribution of major and trace elements in agricultural soils and *Medicago sativa L* of District of Irrigation 03 (DR03) in the State of Hidalgo, México and their relationship with physical-chemical characteristics of soils irrigated with raw wastewaters. Multivariate analysis of the data (Pearson correlation, principal component analysis (ACP), regression, discriminant analysis, mathematical models, etc) quantitatively confirmed that: (*i*) there was significant correlation among the irrigation time, pH, organic carbon (OC) and the concentration of the total and Pb bound to organic matter fraction (Pb_m), Cr and B bound to iron and manganese oxides and exchangeable was found (*ii*) the contents of OC, N_T and Pb_m showed an accumulation dynamics with two or three phases with the irrigation time variable.

INTRODUCTION.

The trace elements refer to elements present at low concentration (mg/kg or less) in agroecosystems. Some elements such as As, Hg, Cd, Pb, Cr and Ni have toxic effects on living organism and are often considered contaminants. Soil contamination with heavy metals and toxic elements due to parent materials or point sources often occurs in a limited area and is easy to identify (He et al. 2005). Inputs of trace and spacing elements through human activities have been increased since the last century. Both industrial and agricultural operations contribute to the greater of trace elements in soil. The input of metals through irrigation varies markedly from location to location and it could become more significant than contamination from point sources.

In countries with extended arid and semi-arid regions, wastewater is a valuable resource and its agricultural reuse is widely practiced. For instance, the amount of wastewater currently used in Israel for agricultural purposes amounts to 1200 Mm3/yr or 162 m3/cap. yr (Haruvy, 1997) whereas, in Mexico, according to Comisión Nacional del Agua (CNA) &

Secretaria de Recursos Hidráulicos (1990) and Peasey et al., (2000), nearly 3132 million m3 / yr of wastewater is used for agricultural irrigation (31.3 m3/cap. yr) (Peasey et al. 2000).

The DR03 has a surface area ca. 45,000 ha; the number of inhabitants in this region is 500, 000 persons, with 27,500 farmers. Its annual agricultural production in 1998 consisted of 3,104,434 ton alfalfa, 526,650 ton of corn, 97,153 ton of forage oat, 24,030 ton of bean, 15,410 ton of marrow, 14,688 ton of green chili, 17,941 ton of tomatoes (green plus red varieties), among others (Instituto Nacional de Estadística e Informática, 1999). Crops grown in this area are mainly consumed by the populations of Mexico City and Pachuca (capital city of Hidalgo State) since they are the principal market outlets for the production. The annual money value of the agricultural production is nearly 100 million American dollars.

In Mezquital Valley, the wastewater is used as a source of irrigation water as well as a source of organic matter (soil conditioner and humus replenisher) and plant nutrients (such as nitrogen, phosphorus, and potassium) allowing the farmers to minimize the costs of mineral fertilizers. Since the precipitation at the DR03 is relatively low (450 mm/yr; in contrast, the evaporation can reach values up to 2100 mm/yr), (British Survey & Comisión Nacional del Agua, 1995), the irrigation with wastewater has become an indispensable practice for sustaining the agricultural production since 1896 (British Survey & Comisión Nacional del Agua, 1995). At the DR03, flooding is the main irrigation technique used and the applied amounts range between 80 to 140 cm/yr (British Survey & Comisión Nacional del Agua, 1995), although it has been reported up to 200 cm /yr for alfalfa (Medicago sativa) (Siebe & Cifuentes, 1995). Most of the irrigated water is raw wastewater consisting of a mixture of municipal sewage water and a substantial share of industrial effluents. This is of concern; because the wastewater contains several potentially toxic trace organic and inorganic substances, such as heavy metals, boron, salts, etc., that may negatively affect the long-term productivity of the soil, the animal and human health (Bhari, 1999).

MATERIALS AND METHODS.

Soil and plants analyses. The soil samples (32 sites) were air dried and sieved (mesh 10 ASTM, < 2 mm) before analysis, and were collected from the Ap horizon (30 cm depth topsoil). Composite samples for each site consisted of 13 cores of soil from 3 adjacent plots (total of 39 cores). The cores were mixed into one composite sample for each soil and analyzed by triplicate, using the method recommended by the Mexican Standard NOM-021-SEMARNAT-2000 (Diario Oficial de la Federación, 2002). The metals in the soil were sequentially extracted following a slight modification of the Tessier's method (Tessier et al. 1979) as described by Lucho-Constantino et al. (2005), although in this work we will only report total contents. Crops grown on soils at selected sites, where collected and washed in 3% HCl to eliminate air borne pollutants in the laboratory after sampling and then dried in an oven at 65° C for 24 h. Plants monitored was *Medicago sativa L.* (alfalfa) The plant samples were ground in a stainless steel grinder. Ten milliliters of concentrated nitric acid was added in to 0.25 g of homogenization sample in a Teflon vessel and digested for 10 min in microwave oven Mars X. The extracts from soils were analyzed for As and Hg using a flame atomic absorption spectrophotometer (Varian SpectrAA 800 equipped with Zeeman device, with hydride generation for As and cold vapor for Hg). Extracts were analyzed for other trace metals (Cd, Cr, Pb), Na, Mg, K, Ca and B, using the inductive coupled-plasma equipment 3000XL Perkin Elmer, method 6010 (USEPA, 1986). Freshly bi-distilled water was used and reagents used for AAS were ultrapure and further purified by chelation-extraction (Welz, 1985). Quality control for total metals included the analysis of a standard reference soil from

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the National Institute of Standards and Technology (SRM 2709). The recoveries ranged from 96.5 to 104% and the coefficient of variation was between 3 and 10% maximum in triplicate analysis. Analytical grade reagents were used throughout our study.

Statistical analysis.

Data analysis was carried out using SPSS v. 12 statistical packages. Principal Component Analysis and Pearson correlation were used to analyze the multivariate relationships among soil properties, and major and trace element concentrations.

RESULTS AND DISCUSSION

We carried out a principal component analysis (PCA) on pooled data of soil physicochemical characteristics and elements (mayor and trace) partitioning in order to better understand their interrelationship and to explore the reduction of the experimental variables. The figure 1 exhibits the main component 1 (CP1) has associate to elements draws up and anions (carbonates and bicarbonates Cl^-, SO_4^{-2}, NO_2^-, NO_3^-), Total Nitrogen(TN), Electrical conductively (EC), sand, silt, Total Carbon (TC), OC, pH, Cation Exchange Capacity (CEC) with irrigation time. Component CP1 explains the 25.91% of the variance of the experimental data. This association suggests the PC1 represents the denominated variable "Effect of the irrigation time in agricultural soils of DR03 and 100" (figure 1, blue ellipse). In this figure a light acidification of soils, as well as the diminution of the carbonate and bicarbonates content can be observed. An increase of the sand content, as well as the silt decrement is evident in soils. It is important to indicate that during the soils sampling with greater irrigation times < 42 years, some presented remainders of $Ca(OH)_2$, common practice for the remediation of soils that display acidification problems. The time of irrigation with residual water it seems to have increased the content of TN and OC (figure 1) in soils of the DR03. Main component 2 (PC2) is associated to the soils with have a short time of irrigation (to see figure 1, red ellipsis). It is possible to be denominated to this new variable like to "salinization (salinity)". The PC2 has associate to the EC and the contents of SO_4^{2-} and Cl^-, as well as contained of total boron (B_T) and exchangeable and soluble boron (B_i) and some trace elements.

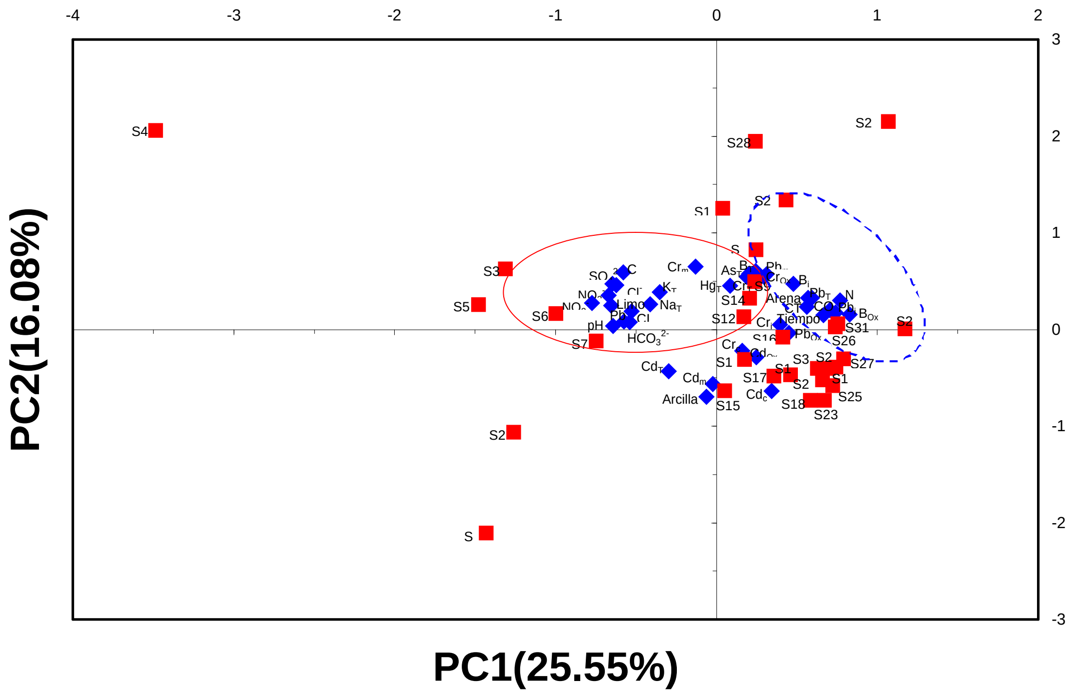

Figure 1. Loading plots a PCA of physicochemical characteristics and major and trace elements in agricultural soils of DR03, Hidalgo. CP1 vs CP2.

Lead average concentration (17.26 – 18.08 mg/kg) in tissues (leaves and stem, respectively) of *Medicago sativa L.* was higher than the typical concentration of trace elements in plants (Lucho et al., 2005), reason why represents a possible risk the health of the animals that consumes these crop. The presence of Hg in alfalfa in most higher concentrations to the found one in European countries is important to take it in account because the rank of concentrations in soils is smaller of 0.1 mg kg^{-1}, which makes suppose that the source of contamination of this metal in the crops can be due to the atmospheric deposition and not to the irrigation with residual water.

CONCLUTIONS

The use of wastewater for irrigation of agricultural soils seems to have increased the contents of organic carbon (OC) and the concentration of the total and Pb bound to organic matter fraction (Pb_m), Cr and B bound to iron and manganese oxides and exchangeable was found and pH showed a significant effect the tendency of acidification of agricultural soils by the wastewater use.

The contents of OC in soils presented an accumulation dynamics in 3 phases: 1) Sequestration, 2) Neutrality and 3) Loss of the content of CO (Emission) with respect to the irrigation time variable.

, N_T and Pb_m showed an accumulation dynamics with two phases with the irrigation time variable. 1) Sequestration of N_T and 2) apparent balance in soils (Neutrality) without arriving at the saturation.

REFERENCES

Bahri, A., 1999. Agricultural reuse of wastewater and global water management. *Water Sci. Technol.* 40, 339-346.

Diario Oficial de la Federación. Norma Oficial Mexicana: NOM 021-SEMARNAT-2000. Que establece las especificaciones de fertilidad, salinidad y clasificación de suelos. Estudios, muestreo y análisis. México (In Spanish); 2002.

Geological Survey and Comisión Nacional del Agua, 1995. Impact of wastewater reuse on groundwater in the Mezquital Valley, Hidalgo State, México. Phase I Report.

Haruvy, N., 1997. Agricultural reuse of wastewater: nation-wide cost-benefit analysis. Agriculture Ecosyst. Environ. 66, 113-119.

He, L.Z., Yang, E.X. & Stoffella, J.P. 2005. Trace elements in agroecosystems and impacts on the environment. *Journal of trace elements in Medicine and Biology*. In press.

INEGI, 1999. www.inegi.gob.mx/estadistica/espanol/economia/ganaderia/gan_01.html

Peasey, A., Blumenthal, U., Mara, D., Ruiz-Palacios, G., 2000. A review of policy and standards for wastewater reuse in agriculture: a Latin American perspective. WELL Report No. 68 Part II. London School of Hygiene and Tropical Medicine and Loughborough University, UK. pp. 74.

Siebe C., 1995. Heavy metal availability to plants and soils irrigated with wastewater from Mexico City. *Water Sci. Technol.* 32: 29-34.

Tessier A, Campbell PGC, Bisson M., 1979. Sequential extraction procedure for the speciation of particulate trace metals. *Anal. Chem.* 51: 844-851.

USEPA, 1986. Test methods for valuating solids waste. Volume I B; Laboratory Manual Physical/Chemical Methods. Cincinnati, OH.. 1-17.

Welz B. *Atomic Absorption Spectrometry*. 2nd, 1985. Edn.VCH GmbH, Weinheim, D-6940. Germany. English translation by Christopher Skeggtish.