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Determination of the water irrigation quality on the heavy metals concentration in agricultural soil and maize cultivated in the Valle del Mezquital, Hidalgo, Mexico

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Abstract

Determination of the water irrigation quality on the heavy metals concentration in agricultural soil and maize cultivated in the Valle del Mezquital, Hidalgo, Mexico The Valle del Mezquital, located in Hidalgo State, Mexico, is the largest area around the world irrigated with no treated wastewater generated in the Mexico City Valley. In order to determine the effect of the quality water on the heavy metals concentration in agricultural soil and maize samples, an analytical study was carried out in experimental agricultural fields irrigated with wastewater treated under different treatment levels.

The irrigation water analyzed were: rain water (CTR-W), no treated wastewater (NTR-W) and wastewater anaerobically digested (ADG-W) and were physically and chemically characterized; the pH, electrolytic conductivity, organic matter, carbonates, nitrates and nitrites, metals (Fe, Zn, Mn, Cu, Cr and Pb) were determined in water samples by using spectrophotometric methods. The soil samples were analyzed and the same parameter were determined. The metal concentration in maize samples was determined as in soil and water samples. The data were linearized by Kruskall Wallis method and the statistical analysis was performed. It was not found an effect of the irrigation water on the heavy metal concentration in soil; contrarily the concentration of metals in maize samples increased in soils irrigated with no treated wastewater; the organic matter and salinity as electrolytic conductivity in soil increased.

Heavy metals; Agricultural soil; Maize; Wastewater; Valle del Mezquital

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Introduction

Heavy metals are ubiquitous in the environment, as a result of both natural and anthropogenic activities, and humans are exposed to them through various pathways (Wilson and Pyatt, 2007). Wastewater irrigation, solid waste disposal, sludge applications, vehicular exhaust and industrial activities are the major sources of soil contamination with heavy metals, and an increased metal uptake by food crops grown on such contaminated soils is often observed. In general, wastewater contains substantial amounts of beneficial nutrients and toxic heavy metals, which are creating opportunities and problems for agricultural production, respectively (Chen et al., 2005; Singh et al., 2010).

Contamination of soils by heavy metals, such as Cd, Ni, Zn, Pb, and Cu, has increased dramatically during the last few decades (Chibuike and Obiora, 2014) due to human activities (Morgan, 2013; Chibuike and Obiora, 2014). Contamination of soils by heavy metals is now widespread (Al- Nagger et al., 2013). Land degradation caused by heavy metals has significant adverse effects on the environment and ecosystem worldwide (Li et al., 2013; Chen et al., 2015). Dispersion of heavy metals in irrigated soils and the plants that are growing results in the contamination of food that may be hazardous to humans and animals (Jolly et al., 2013).

The most general symptoms of metal phytotoxicity are stunting and chlorosis (Påhlsson, 1989). It is not clear whether or not heavy metals in leaves interfere with photosynthesis. Various laboratory experiments have indicated that photosynthesis is influenced by heavy metal ions.

Inhibition of the whole plant net photosynthetic rate which was accompanied by reduced transpiration rate has been attributed to a Cd-induced closure of the stomata (Clijsters). Heavy metals reduce the chlorophyll content (Assche, 1990). Schützendübel et al. (2002) suggested that many heavy metal effects on plant metabolism are most probably of only secondary importance.

The Mezquital Valley is one of the oldest and largest examples worldwide of an agricultural irrigation system using municipal wastewater (Jiménez and Chávez, 2004). At present, 900 km^2 of previously semi-arid land is irrigated with untreated wastewater. As a consequence of wastewater irrigation, the original flow of the Tula River, the main river in the valley, has increased from 1.6 to 12.7m^3/s in the last 50 years (DFID, 1998). Bacterial contamination, chemical pollution of water, and contamination of vegetable crops through irrigation water are the main problems associated with wastewater irrigation in the Mezquital Valley (Downs et al., 1999).

The aim of this experimental work was determine the effect of the wastewater irrigation quality in terms of heavy metals concentration of the quantitative presence of these elements in agricultural soil and biomass of the maize cultivated in it.

Materials and Methods

All the samples were taken per triplicate, for the soil samples nine sites were selected per treatment and the same number of biomass samples, three samples per triplicate were taken for water samples per treatment. The number of samples was: 81 samples for soil, plant and biomass, the total number of samples was 243.

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Sampling site and soil characteristics

The soil samples were taken from agricultural soil from the municipality of Tula de Allende (N.L. 19º58´.W.L. 99º18´) and cultivated with maize and irrigated with wastewater treated at different levels e.g. no treated wastewater (NTW), anaerobically digested wastewater (ADW) and rainwater (RW) used as control. The simple consisted in one kilogram of soil taken by using a soil non metallic sampler.

The parameters determined were: Electrolytic Conductivity (EC), pH, Total Carbon (TC), Total Nitrogen (TN), Particle Soil Distribution (PSD) and the follow elements B, Se, Cr, Al, Cd, Cu, Fe, Mn, Ni, Zn, As and Pb.

Wastewater samples

The wastewater was sampled before receiving the anaerobic treatment (NTR-W) and after the anaerobic treatment (ADG-W), the rain water was sampled (CTR-W). All the water samples were physical and chemically characterized. The water simple of water consisted in 500 ml of water, storaged in acidic solution for the metal determination and in a preservative solution

The parameters determined in water samples were: turbidity, pH, EC, Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), TN, Total Phosphorus (TP) and the same elements determined for soil samples.

Biomass samples

The maize plants were selected in the productive stage (presence of cobs). The biomass was taken from roots, plant stem and leafs.

The biomass simple was taken by using a plastic knife in order to avoid the metal contamination.

Pre treatment of samples

Soil samples

The soil samples were passed separately through a five mm sieve for removing organic and mineral matter. The samples were storage in plastic bags until the laboratory analysis.

Water samples

The water samples were transported o the laboratory at 4ºC and then storaged at same temperature and darkness. The acidic digestion for the metals determination was done into the 24 hrs. after the sampling.

Biomass sampling

The biomass was sotareg in paper bags. In the laboratory, the material was selected, washed with distilled water, part of the material was analyzed in fresh, other was dried in an oven at 100 ºC and storaged in plastic bags under darkness conditions until the conditioning for analysis.

Determination of parameters

Soil characteristics

The pH, EC and PSD were determined (Black et al., 1965). The TC content in soil was measured according to the method reported by Tiessen et al. (1993). The N was determined by the Kjeldhal method (modified by Brenmer, 1965).

Water characteristics

The characterization of the wastewater and rainwater samples were done according the methods published by Melcer (2003).

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Biomass

The elements determination was done by using the spectrophotometric method in an equipment SpectrAA 220, Varian, after an acidic digestion according to the modified method of Tüzen (2003).

Results

The table 1 shows the physicochemical values of the analyzed soils.

Site	EC[a] (ds m^{-1})	pH	WHC[b] (g kg^{-1} soil)	Carbon (mg kg^{-1} soil)		Total N (mg kg^{-1} soil)	Particle size distribution (%)			Textural classification
				Organic	Inorganic		Clay	Silt	Sand	
S1	2.3	7.9	900	23481	1435	2658	350	280	370	Clay loam
S2	2.6	7.5	680	19542	1682	1689	340	290	370	Clay loam
S3	2.1	7.0	735	16580	650	890	300	250	450	Clay loam

S1: soil irrigated with no treated wastewater
S2: soil irrigated with anaerobically wastewater treated
S3: soil irrigated with rainwater
[a] EC: electrolytic conductivity
[b] WHC: water holding capacity

Table 1 Physicochemical characterization of analyzed agricultural soils. Average values are shown

The parameters determined to the samples of water are shown in the table 2.

Water	EC[a] (µmhos cm^{-1})	pH	TSS[b] (mg L^{-1})	VSS[c] (mg L^{-1})	FSS[d] (mg L^{-1})	TDS[e] (mg L^{-1})	Turbidity (NTU)	COD[f] (mg L^{-1})	Total N (mg L^{-1})	Total P (mg L^{-1})
NTR-W	0.93	7.4	190	128	62	0.53	265	348	36.5	9.5
ADG-W	0.69	7.6	36	24	12	0.47	48	150	17.8	6.5
CTR-W	-	6.4	-	-	-	-	-	-	-	-

NTR-W: no treated wastewater
ADG-W: anaerobically digested water
CTR-W: rainwater
[a] CE: electrolytic conductivity
[b] TSS: total solved solids
[c] VSS: volatile suspended solids
[d] FSS: fixed suspended solids
[e] COD: chemical oxygen demand

Table 2 Physicochemical characterization of irrigation water. Average values are shown

The elements concentration in biomass, soil and water are shown in table 3.

Sample	B	K	Cr	Cd	Cu	Fe	Mn	Ni	Zn	Pb
					mg kg^{-1} *ds**					
S1	139.4	125.1	45.6	2.5	17.3	20159.5	451.7	23.4	61.7	7.5
S2	126.2	158.3	32.5	1.9	9.8	14769.4	326.8	12.3	38.2	4.2
S3	354.5	251.7	ND	ND	2.7	19860.2	344.4	16.3	40.2	ND
					mg kg^{-1} *db***					
Mz-S1	4.2	35.2	5.2	2.1	7.2	72.3	134.0	3.2	45.2	ND
Mz-S2	3.8	43.7	8.0	ND	4.3	89.4	82.6	7.7	87.6	ND
Mz-S3	3.5	39.8	ND	ND	6.7	82.1	79.5	7.0	35.1	ND
					mg L^{-1}					
NTR-W	0.52		0.022	0.0034	0.014	1.5	.05	.21	.64	0.32
ADG-W	0.32		0.025	0.0042	0.004	0.65	0.10	0.003	0.113	0.12
CTR-W	1.2	15	ND	ND	ND	4.0	21	ND	ND	ND

M2-S1: maize irrigated with non treated wastewater
Mz-S2: maize irrigated with anaerobically digested wastewater
Mz-S3: maize irrigated with unpolluted water
*ds: dry soil
**db: dry biomass

Table 3 Elements concentrations in agricultural soil, irrigation water and maize. Average values are shown

Discussion

Soil characterization

The characterization shows physical and chemical parameters in and average range for soil irrigated with unpolluted water, however the soils under wastewater either untreated and treated irrigation have higher levels in WHC, EC, pH, C and N content, it is due to the composition of the wastewater itself.

The pH of the soils sampled in this experiment ranged from 7.0 to 7.9, although values greater than 8.5 have been reported for these same soils in other experiments (Flores et al., 1997). The values for EC do not reflect a salinization effect.

The irrigation of soils with wastewater is not only important for the addition of available nutrients for plants but for the amounts remaining in soils as can be observed as N and C content (Table 1).

The additions of either wastewater and unpolluted water do not impact on the SPD.

Water analysis

Concentrations of Cr, Cd, Cu, Ni, Zn and Pb in both untreated and treated wastewater were lower than the mean daily amount that can be applied as stipulated by NOM-001-ECOL-1996 (SEMARNAP, 1996). Although the concentrations of heavy metals are low in the wastewater, its application over the years could drive the accumulation in soils and then the absorption by plants, facilitating the bioaccumulation in primary consumers. Many studies carried out in agricultural soils in the Valle del Mezquital that have irrigated with wastewater have reported metal concentrations under the values given by the Mexican environmental normativity. (Mendoza-Márquez, 198; Siebe, 1994).

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Biomass analysis

The average metals concentration in plant tissue (root, steam and leaves) were into the normal range for trace elements e.g., Zn, Fe, Mn and K.

The plants irrigated with unpolluted water did not present detectable values for Cd, Cr and Pb. The tissue of plants under the ADG-W irrigation did not contain detectable Cd concentration.

The Cr was present in plants irrigated with untreated wastewater. The Pb was not detected in plants under any irrigation regime.

Effects on the growth and production in maize plants were not visually detected.

Conclusion

The irrigation with wastewater of agricultural soils in the Valle del provides high amounts of organic matter (C and N), showing positive effects in terms of high crop yields and reducing costs by eliminating the use of fertilizers, however at long term it could bring negative effects by increasing salinity and compaction in soils.

In this study, the concentration of heavy metals in the irrigation water did not exceed the limits according to the Mexican environmental standards; however, the application for long time could increase the concentration in the soils, affecting the future of crop production.

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References

Assche, F. V., & Clijsters, H. (1990). Effects of metals on enzyme activity in plants. Plant, Cell & Environment, 13(3), 195-206.

Black, C. A., Evans, D. D., & Dinauer, R. C. (1965). Methods of soil analysis (Vol. 9, pp. 653-708). Madison, WI: American Society of Agronomy.

Bremner, J. M. (1965). Total nitrogen. Methods of soil analysis. Part 2. Chemical and microbiological properties, (methods of soil), 1149-1178.

Chen, T. B., Zheng, Y. M., Lei, M., Huang, Z. C., Wu, H. T., Chen, H., ... & Tian, Q. Z. (2005). Assessment of heavy metal pollution in surface soils of urban parks in Beijing, China. Chemosphere, 60(4), 542-551.

Clijsters, H., & Van Assche, F. (1985). Inhibition of photosynthesis by heavy metals. Photosynthesis Research, 7(1), 31-40.

DFID, Department for International Development: CNA, Comisión Nacional del Agua; BGS, British Geological Survey; LSHTM, London School of Hygiene and Tropical Medicine; UB, University of Birmingham, 1998. Impact of Wastewater Reuse on Groundwater in the Mezquital Valley, Hidalgo State, Mexico. British Geological Survey Technical Report WC/98/42.

Downs, T. J., Cifuentes-Garcia, E., & Suffet, I. M. (1999). Risk screening for exposure to groundwater pollution in a wastewater irrigation district of the Mexico City region. Environmental Health Perspectives, 107(7), 553.

Flores, L., Blas, G., Hernandez, G., & Alcala, R. (1997). Distribution and sequential extraction of some heavy metals from soils irrigated with wastewater from Mexico City. Water, Air, and Soil Pollution, 98(1-2), 105-117.

Jiménez, B., & Chávez, A. (2004). Quality assessment of an aquifer recharged with wastewater for its potential use as drinking source: "El Mezquital Valley" case. Water Science and Technology, 50(2), 269-276.

Melcer, H. (2003). Methods for wastewater characterization in activated sludge modeling. IWA publishing.

Mendoza Márquez, H., Aguirre Martínez, J., & Athie Lambarri, M. (1981). Land treatment: a viable solution for management of wastewater in the metropolitan area of the Valley of Mexico. In International Conference on the Status of Knowledge, Critical Research Needs, and Potential Research Facilities (pp. 163-93). Academic Press.

Påhlsson, A. M. B. (1989). Toxicity of heavy metals (Zn, Cu, Cd, Pb) to vascular plants. Water, Air, and Soil Pollution, 47(3-4), 287-319.

Schützendübel, A., & Polle, A. (2002). Plant responses to abiotic stresses: heavy metal-induced oxidative stress and protection by mycorrhization. Journal of experimental botany, 53(372), 1351-1365.

SEMARNAP, 1996. Norma Oficial Mexicana NOM-001-ECOL-1996.

Siebe, C. (1994). Akkumulation, Mobilität und Verfügbarkeit von Schwermetallen in längjährig mit städtischen Abwässern bewässerten Böden in Zentralmexiko. Stuttgart: Universität Hohenheim.

Singh, A., Sharma, R. K., Agrawal, M., & Marshall, F. M. (2010). Health risk assessment of heavy metals via dietary intake of foodstuffs from the wastewater irrigated site of a dry tropical area of India. Food and Chemical Toxicology, 48(2), 611-619.

Tiessen, H., & Moir, J. O. (1993). Total and organic carbon. Soil sampling and methods of analysis, 187-199.

Tüzen, M. (2003). Determination of heavy metals in soil, mushroom and plant samples by atomic absorption spectrometry. Microchemical Journal, 74(3), 289-297.

Wilson, B., & Pyatt, F. B. (2007). Heavy metal dispersion, persistence, and bioaccumulation around an ancient copper mine situated in Anglesey, UK. Ecotoxicology and environmental safety, 66(2), 224-231.