Impacto del uso de agua residual en la agricultura

Impact of using wastewater in agriculture

María E. Guadarrama-Brito
Universidad Autónoma Metropolitana
mgb124@hotmail.com

Antonina Galván Fernández
Universidad Autónoma Metropolitana
loralalik@gmail.com

Resumen

La escasez de agua para uso urbano y la dependencia del riego para la producción agrícola en zonas de rápido crecimiento demográfico, han contribuido a que a nivel internacional aumente el interés en el reuso del agua. Existen riesgos para la salud debido a la presencia de microorganismos y contaminantes como los metales pesados y mutagénicos; los primeros impactan a corto plazo, debido a la contaminación de alimentos que pueden provocar, y los segundos impactan a largo plazo, contribuyendo a la salinización de suelos, lo que detrimenta la productividad para eventualmente derivar en el abandono de terrenos. El reuso del agua residual en la agricultura se ha convertido en una necesidad, la cual debe ser considerada como una alternativa, aunque no ha sido evaluada en los aspectos de contenido y migración de contaminantes, en particular de metales pesados.

Algunos de los metales pesados pueden forman parte natural del suelo en cantidades que no resultan tóxicas para los seres vivos; sin embargo, la industrialización ha provocado un aumento de la presencia de estos en las aguas residuales que se utilizan para riego, con el consecuente riesgo para la salud humana y ambiental. El proceso de migración y fijación de contaminantes dentro de un sistema cerrado, dependerá de la capacidad de absorción por parte de los subsistemas agua-suelo-planta, aplicación de tasas de riego (concentración del contaminante), y de la persistencia y toxicidad de los contaminantes.

El estudio aquí presentado, evalúa las tasas de migración de metales pesados presentes en un agua de riego, a través del sistema agua-suelo-planta; la evaluación se realizó con material del distrito de riego 028-Tulancingo que recibe aguas residuales de origen industrial, con presencia de Cobre, Manganeso y Zinc para diferentes grados de impacto.

Palabras clave: agua residual, suelo, planta.

Abstract

The shortage of water for urban use and dependence on irrigation for agricultural production in areas of rapid population growth, have contributed to increased international interest in water reuse. There are health risks due to the presence of microorganisms and pollutants such as heavy metals and mutagenic; the first short-term impact due to contaminated foods can cause, the second to impact long term, contribute to soil salinization, which detriment productivity, and eventually lead to the abandonment of land. The reuse of wastewater in agriculture has become a necessity, which must be considered as an alternative, which however has not been evaluated in terms of both content and migration of contaminants, including heavy metals.

Some of the heavy metals can form a natural part of the soil in amounts that are not toxic to living things; however, industrialization has led to increasing their presence in wastewater used for irrigation, with the consequent risk to human and environmental health. The process of migration and fixation of contaminants within a closed system depends on the capacity of absorption by the sub -soil water- plant irrigation application rates (pollutant concentration), and the persistence and toxicity of pollutants.

The study presented here evaluates the rates of migration of heavy metals in irrigation water through the water-soil-plant system; evaluation was performed with material Irrigation District 028-Tulancingo that receives wastewater from industries, with the presence of copper, manganese and zinc for different degrees of impact.

Key words: waste water, soil, plant.

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Introduction

Agriculture and rural areas of Mexico have been significantly impacted by the recent implementation of agricultural policies. Although the achievements of this process have been really beneficial for the economy as a whole, the results in terms of achieving greater rural development have been below the expectations held at the beginning of the reforms.

Changes in land use, urban pressure on agricultural land and the absence of proper management of watersheds in recent decades generated a worsening of the problems of erosion, deforestation and flooding. On the other hand, economic development presented by the country, has caused great pressure on renewable natural resources, having been diagnosed with various problems such as soil and water overuse and pollution of the same, as a result of overfishing; situation that causes serious conflicts for different types of users within watersheds.

The need to protect the environment of increased pollution levels, has acquired international importance; UN through the Millennium Development Goals (UN, 2010) states that the objectives 7 and 7.3 are "incorporate the principles of sustainable development into country policies and programs and reverse the loss of environmental resources, and reduce . by half the proportion of people without sustainable access to safe drinking water and basic sanitation, respectively "These are the most backward objectives globally, while at the national level are presented huge disparities: while in large urban centers Mexico City and Guadalajara, access to clean water is almost 100%, dispersed rural communities do not exceed 35%. This problem stems from the effective availability of water has been reduced by imbalances caused by the growth in demand, inefficient use and increasing pollution levels (Guzman et al., 2006).

The imbalance between water demand and availability depends on three things: the first is the natural availability, which is the amount of water likely to leverage and that depends on the weather and geography; secondly is population growth, which not only involves the increase of the population, but also the increasing demand of satisfaction for the population, so it requires more food, supplies direct and indirect use and services. In the third part it has significantly increased the volume of wastewater is discharged without treatment on natural streams and agricultural land, and are the product of wastewater discharges.

Treatment and reuse of water play a fundamental role in the administration and management of this resource in all countries. The most common types are the reuse of treated water use in agricultural, industrial, recreational and recharge activities. As for groundwater recharge in several countries they have conducted research to measure public health associated with pathogens, viruses, heavy metals impacts and, in general, transport of pollutants. Since 1992, regulations have been developed to control this activity (Arreguín et al., 2000).

One of the alternatives to try to remedy in part the lack of water, is to use the waste water for agricultural irrigation, generated both by the urban population, for industries. However, few studies related to healthcare quality and agricultural productivity of such water resources. In Mexico, there is little research on the use of nutrients, assessment of the sanitary quality in certain crops, and the physical and chemical properties of soil due to irrigation with wastewater (Rascon et al., 2005).

Use in irrigation of low quality water is an increasingly common in the world practice, because it is a cheap source for areas with erratic rainfall patterns and the increasing scarcity of water for irrigation (Sancha et al., 2005; Rivera 2007).

The use of wastewater for irrigation has its origins in the construction of a sewage outlet for the Valley of Mexico. In 1890 they began to use these waters in the region of Valle del Mezquital in Tula, Hidalgo, for flood irrigation of cereals, vegetables and forage such as alfalfa. There was no sanitary control, until the emergence of the NOM 032 and 033 in the version of 1988. Ecological Technical Standard NOM 067 completed the regulatory framework, which is now included in the NOM 001 / ECOL-l96 (Siebe, 1994; Jimenez et al., 1996; Arreguín et al., 2000; Vivanco et al, 2001)..

According to the information of the basin organizations and local addresses Conagua to December 2011 were in the country 2289 formal operation plants with a total installed capacity of 137.1 m3 / s (De la Pena et al ., 2013). The collected flow for 2011 was 218 m3 / s, which were treated 117.9 m3 / s, this is a treatment rate of 54.1% and the rest is discharged into water bodies process prior sanitation (Conagua, 2012).

The main use of wastewater in Mexico is agricultural. The area devoted to agriculture in Mexico varies between 20 and 25 million hectares, with a harvested area of 18 to 22 million hectares per year (CONAGUA, 2006). Table 1 shows the information on national agricultural area is presented.

Table 1. Agricultural surface.

	ha	%
Superficie agrícola nacional	31 017 889.0	
Superficie cosechada	18 575 613.6	0.599
Superficie de temporal	16 209 962.2	0.523
Superficie de riego	5 414 055.0	0.175
Superficie regada con agua residual	280 000	0.009

Construcción propia, datos INEGI 2005.

However, despite the importance of agricultural irrigation and its potential impact on human and environmental health, there is no monitoring and evaluation of the impacts related to the use of wastewater in agriculture, such as: soil salinization, pollution surface and groundwater, fixation and migration of contaminants in soils and plants, and its potential impact on food consumption by the human being.

Exposure to these pollutants is typified in three formats, depending on the human health effects: mutagenic, toxic and bioaccumulative (PAHO and EPA Rules, 2014); causing effects on the first DNA strand, modifying genetic information structures and therefore brittleness inducing individuals against certain diseases or environmental conditions. The latter refers to immediate or within the lifetime of the exposed individual damage and modifying tissues and organs; the latter refers to the accumulation of elements in certain tissues of individuals, under certain conditions and rates no adverse health effects, but that limits be exceeded, age or environmental conditions trigger a series of conditions.

- Toxic Damage: degenerative effects on biological activities and tissues in the short term. These effects can be mitigated under specific driving conditions and medication. This type of damage is evident on economically active population, with working time of 5 or more years, is emphasized in the reproductive age for women, and towards the end of the production stage in men.
- Bioaccumulation: The elements accumulate in any tissue passively; however, the environmental conditions or limits exceeded effects are not reversible chain inducing degenerative effects on organs. Examples are industrial tuberculosis, which deteriorates lung tissue and climate change at lower temperatures triggers the clinical picture. They identified mainly with the population in withdrawal process with changing habits and constant decay processes in health. In another spectrum of the population, men with degenerative work processes are derived, so it is difficult to differentiate.
- Mutagens: The mutagenic compounds are those where high cation exchange capacity come to modify the protein chains of DNA, which in the first instance or replace broken sections of the chain. Most point mutations are of order, so that no powerful manifestations in the individual. The main effects are on the molecular level, where individuals show vulnerability to certain conditions, environmental conditions or chronic conditions. The spectrum of population which is most identified in infants and children in development.
- At present there are standards: NOM 001-ECOL-1996, NOM-127-SSA1-1994 and National Water Law, which are responsible for putting limits on discharges in content and type of pollutants; These standards are the first frontier in environmental protection and human beings in the country, however, date back to the nineties, although recently in 2006 and 2010 revisions has incorporated a number of new concepts about environmental protection they have not been effectively evaluated, as is the setting and the migration of heavy metals.

Today we know that migration routes of pollutants and the effects of these are more extensive than previously thought. Thus, wastewater discharges may reach humans by a) agricultural irrigation, b) direct consumption of livestock, c) use of man, but the impacts will be determined by the absorption capacity of each element in the chain of transmission (figure1).

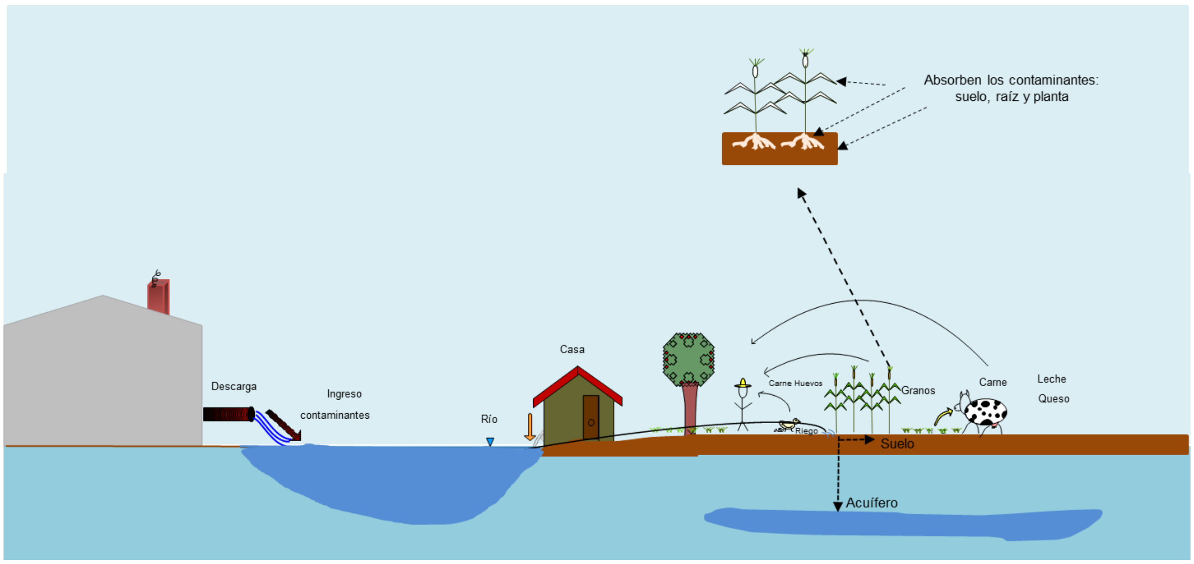


Figure 1. contaminant migration routes.

From this figure possible contaminant migration routes are determined from the water with which it is watered, even human; Figure 2 shows the possible migration routes.

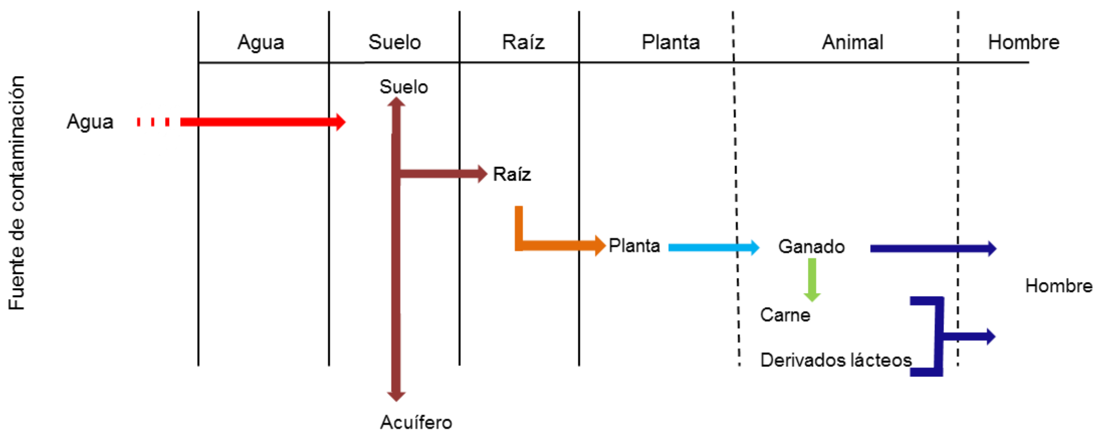


Figure 2. Map of migration of contaminants water-man.

As shown, the route is through food derived from livestock such as: meat and dairy. The latter is no accident, according to the rules we know that the impact of heavy metals in humans when plant foods are ingested directly are clearly identifiable, so that has been established as a measure of protection "may only be irrigated with wastewater containing heavy metals, plants intended for animal consumption ".

You need to determine downloads thresholds under the new contexts of both the water quality and the management of agricultural irrigation, as they determine the rates of contaminants likely to impact the human being.

MATERIALS AND METHODS

To determine the absorption and fixation of a contaminant through an ecosystem, it should be understood; an ecosystem is the space formed by biotic and abiotic components that interact to fulfill vital functions of reproduction and accumulation of biomass; when the process is stable, it is said to be in balance. For this, the ecosystem is open to capture energy and materials from external sources (eg, rain and solar radiation). After making their functions, throw processed materials and energy (Odum, 1992) abroad in the form of waste. Natural ecosystems contained within the biosphere support from solar input, which once it has penetrated and has been used by the system, flows out as heat and other processed forms of organic matter and other materials. In the environment, the chemicals concerned several times without losing their usefulness; biogeochemical cycles are closed for materials, but open to input and output power, where the biochemical decomposition of the materials supplied to turn other materials reuse for other elements of the ecosystem. However, the operation of closed cycle is absent in human systems, as these are based on the idea of energy availability and unlimited resources, unlimited volume also generating waste. The residues are defined as those materials and energies are lower quality or unusable within the system, so they must be outsourced, ie ecosystems maintain internal balance balance or naturally.

Balance

Balance is the valuation in terms of mass and / or energy; It is the way the internal accumulation rate (fixing) materials / energy of a closed system and outsourcing rates are determined. It is defined as pollutant materials are disposed such that:

$$\frac{\Delta S}{\Delta t} = \frac{\mathrm{I} - \mathrm{O}}{\Delta t} = 0$$

Where:

Δs= accumulation system (fixing)

I= logon of a component or material.

O= output system component or material.

For the assessment of contaminants in the water that is applied as soil irrigation, we have:

$$\frac{\Delta S_{Suelo}}{\Delta t} = \frac{\mathrm{I} - \mathrm{O}}{\Delta t}$$

I = $[C_{Riego}]$

O = $[C_{Riego}]$

ΔS = Suelo = $[C_{Inicial} + C_{Suelo}]$

In the case of soil flow at the root, we have:

$$\frac{\Delta S_{Raíz}}{\Delta t} = \frac{\mathrm{I} - \mathrm{O}}{\Delta t}$$

I = $[C_0] – [C_{Suelo}]$

O = $[C_{Planta}]$

ΔS = $[C_{Raíz}]$

In the case of flow from the root to the plant, we have:

$$\frac{\Delta S_{Planta}}{\Delta t} = \frac{\mathrm{I} - \mathrm{O}}{\Delta t}$$

I = $[C_0] – [C_{Raíz}]$

O = 0

$\Delta S = [C_{Planta}]$

Such that the system is described in Figure 3:

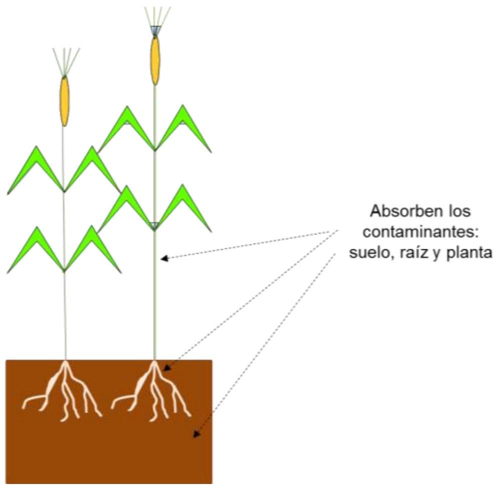


Figure 3. water-soil-plant root system.

Where it is identified that the entry of contaminants into the system is contaminated water, there will be an accumulation in a) soil, b) root c) plant, but there will be a migration of a) water ground, b) soil as a result, c) a plant root, the latter being responsible (intake) the impact on animal and human health.

The cation exchange capacity (CEC) is a measure of the amount of cations that can be absorbed or held by a floor; in general the higher the cationic exchange capacity, the greater the ability to fix metal floor. CIC is the initial ground: 85.1 mg / L.

Materials and methods

According to raised concentrations of pollutants, classified as heavy metals, Irrigation water, soil, root, plant were evaluated, and this value is defined as the fixed rate, such that:

Contaminant rate = [C] Cu, Mn, Zn -------------------------------------- - Equation 1

And the difference between them as emigrated rate:

Migration rate = [Ci] Cu, Mn, Zn - [Ci-1] Cu, Mn, Zn --------------------------- - Equation 2

An experiment was established with the following characteristics:

1. The soil used is of a parcel located within the module II in Tulancingo, Hidalgo; a process of homogenization soil selection (to 9.51 mm sieve. 2 mm- and D10) and the determination of structural characteristics and content of nutrients and pollutants was performed.
2. An irrigation system concentration of 5 blocks with 4 repetitions per case, plus a white or witness element was established.
3. A forage crop was established, since consumption is limited to alfalfa. Alfalfa seeds of the variety San Miguel, used by farmers in Irrigation District 028 were used.
4. Five grams of seeds were placed uniformly, subsequently watered with 150 ml of water brought periodically residual Module II Tulancingo.

The concentration of the solutions was based on the limits established by NOM-CCA / 032-ECOL / 1993 as well as two lower limits concentrations two above these, and a witness. See Table 1.

Table 1. Concentration of heavy metal solutions according to NOM-CCA / 032-ECOL / 19932.

Metal *(mg/L)*	**Límites inferiores a la norma**		**Límites de acuerdo a la norma**	**Límites superiores a la norma**	
Cobre	0.05	0.1	0.2	0.3	0.4
Manganeso	0.05	0.1	0.2	0.3	0.4
Zinc	0.5	1	2.0	3	4

Five three known concentrations of contaminants were generated: copper, manganese and zinc solutions were prepared with concentrations of the standard required for the preparation of the necessary irrigation volumes (Table 2).

Table 2. accrued watered milliliters for each cut.

Time	1	2	3	4	5
Cobre	80	240	560	1040	1680
Manganeso	80	240	560	1040	1680
Zinc	190	571	1333	2476	4000

Four irrigations with the concentrations shown in Table 2, at intervals of 14 days and five collections of ground periodically performed two months. After the second month of planting began with the first collection of plant. Volumes include irrigation, as the concentrations of heavy metals, are not homogeneous. Table 3 shows the volumes of irrigation block.

Table 3. milliliters watered accumulated for each block (concentration).

Concentración	1	2	3	4	5
Cobre	4	12	28	52	84
Manganeso	4	12	28	52	84
Zinc	9.5	28.6	66.7	123.8	200.0

RESULTS

Analyzes in initial soil sample

Tests on a soil sample at the beginning of the experiment were: Texture Bouyoucus by the method (AS-09 method); pH (AS-2 method); Electrical conductivity (EC) with the method of soluble salts; salinity (soluble ions); and organic matter (Walkley Method and Back), bulk density (DA) with the method of the specimen, heavy metals: copper, zinc and manganese (DTPA method); NO3, and NH4 (KCl (soil) method); calcium, magnesium, sodium and potassium interchangeable (ammonium acetate method); phosphorous (Olsen method); Boro (H-Azomethine) Methodologies taken from the NOM-021-RECNAT-2000

Manual Van Reeuwijk. Heavy metals were determined using the technique of atomic emission spectrometry analyzed in optical emission spectrometry with inductively coupled plasma (ICP-OES), Perkin Elmer Optima 5300DV model.

The initial classification of textural soil is sandy loam indicates that the analysis results of the sample are presented in Table 4.

Table 4. Initial analysis results on the floor.

pH	Unidades de pH	7.87
CE	*dS m*$^{-1}$	0.1168
D. A.	*gr cm*$^{-3}$	1.39
M.O	%	0.57
NO_3	*meq/L*	0.011
NH_4	*meq/L*	0.446
Boro	*meq/L*	0.029
Fósforo	*meq/L*	0.401
Cu	*meq/L*	0.003
Zn	*meq/L*	0.082
Mn	*meq/L*	0.063
Fe	*meq/L*	0.006
Bases intercambiables		
Calcio	*meq/L*	26.694
Magnesio	*meq/L*	8.062
Potasio	*meq/L*	5.946
Sodio	*meq/L*	1.847

The pH of the sample mediadamente initial soil is alkaline and organic matter content is low.

Determination of migration rates

The determination of heavy metals in different soil samples and root plants for different irrigation blocks (time), are described in NOM-021-RECNAT-2000, which establishes specifications fertility, salinity and classification soils. Similarly, the analyzes were performed by atomic emission equipment, analyzed in optical emission spectrometry with inductively coupled plasma (ICP-OES). The results are presented in Table 5.

Table 5. Data obtained.

		ACUMULADOS DE Cu			ACUMULADOS DE Mn			ACUMULADOS DE Zn		
		meq/l								
	TIEMPO	Suelo	Raíz	Planta	Suelo	Raíz	Planta	Suelo	Raíz	Planta
Concentración 1	1	0.008	0.003	0.003	0.240	0.036	0.032	0.010	0.013	0.009
	2	0.016	0.006	0.005	0.517	0.058	0.069	0.024	0.023	0.021
	3	0.023	0.011	0.007	1.555	0.089	0.099	0.035	0.033	0.030
	4	0.031	0.017	0.009	2.425	0.155	0.128	0.047	0.044	0.039
	5	0.049	0.021	0.011	3.836	0.251	0.155	0.057	0.058	0.050
Concentración 2	1	0.005	0.003	0.002	0.217	0.021	0.030	0.006	0.017	0.009
	2	0.010	0.006	0.004	0.609	0.040	0.062	0.014	0.033	0.019
	3	0.016	0.012	0.006	1.932	0.090	0.099	0.022	0.046	0.028
	4	0.020	0.017	0.008	2.408	0.132	0.125	0.030	0.056	0.038
	5	0.033	0.021	0.011	3.424	0.199	0.150	0.039	0.067	0.049
Concentración 3	1	0.006	0.003	0.004	0.221	0.022	0.043	0.009	0.013	0.019
	2	0.010	0.006	0.007	0.287	0.036	0.087	0.018	0.026	0.037
	3	0.014	0.010	0.010	0.809	0.064	0.128	0.029	0.034	0.053
	4	0.020	0.014	0.013	1.167	0.126	0.167	0.041	0.044	0.067
	5	0.029	0.018	0.016	2.019	0.185	0.201	0.050	0.055	0.087
Concentración 4	1	0.004	0.003	0.004	0.194	0.024	0.046	0.005	0.009	0.019

	2	0.010	0.006	0.007	0.606	0.039	0.093	0.020	0.019	0.038
	3	0.015	0.011	0.011	2.546	0.075	0.156	0.042	0.027	0.068
	4	0.020	0.015	0.014	4.734	0.117	0.196	0.070	0.039	0.088
	5	0.032	0.019	0.018	6.026	0.142	0.225	0.087	0.051	0.105
Concentración 5	1	0.006	0.003	0.003	0.452	0.033	0.033	0.016	0.012	0.014
	2	0.012	0.005	0.006	1.961	0.047	0.075	0.032	0.024	0.028
	3	0.017	0.009	0.011	3.993	0.083	0.140	0.062	0.035	0.062
	4	0.022	0.015	0.014	5.285	0.107	0.170	0.086	0.044	0.077
	5	0.031	0.020	0.018	7.351	0.162	0.197	0.105	0.059	0.096

ANALYSIS AND DISCUSSION

From the information on the concentrations of heavy water, soil, and plant roots metals, we have to build in each time interval is shown in Figures 1 (copper), 2 (manganese) and 3 (zinc).

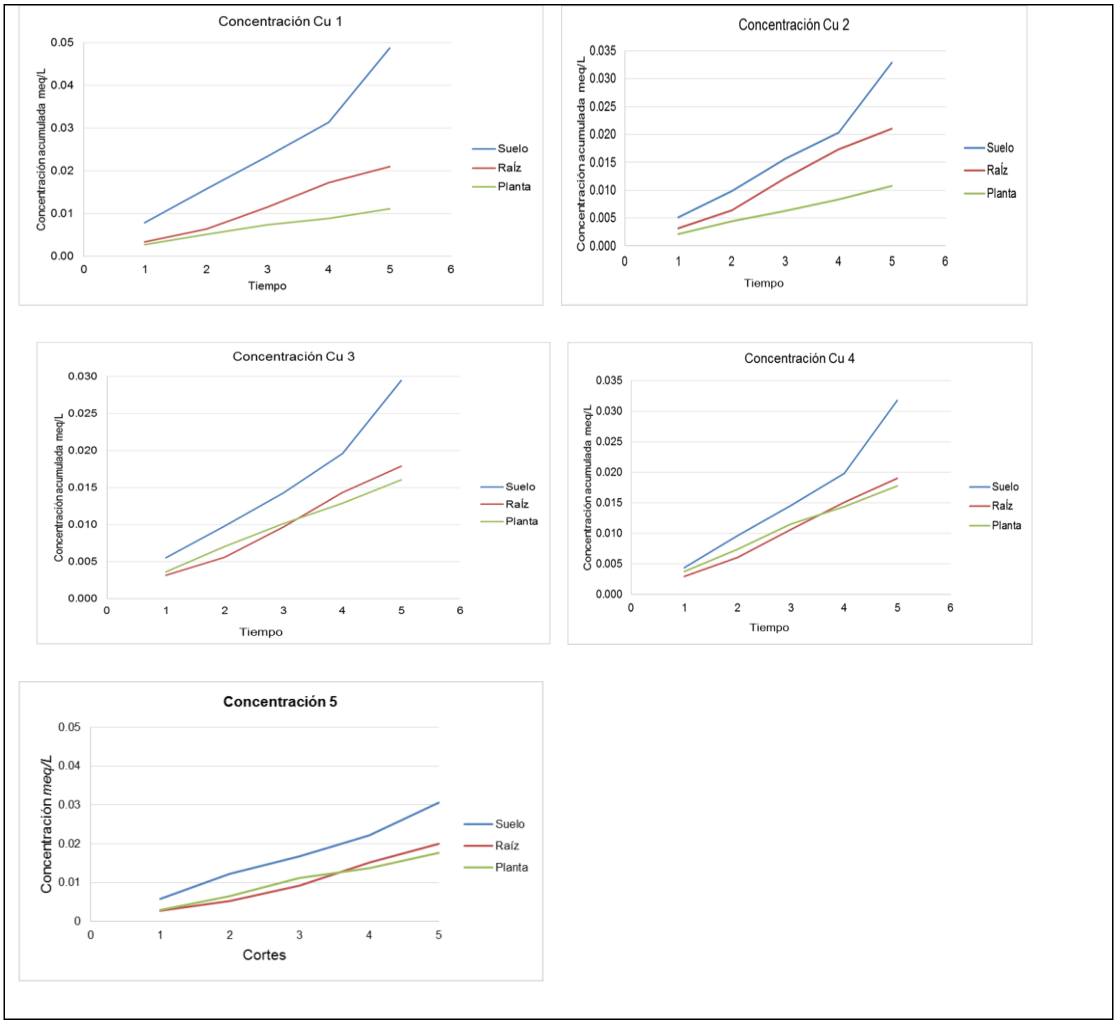
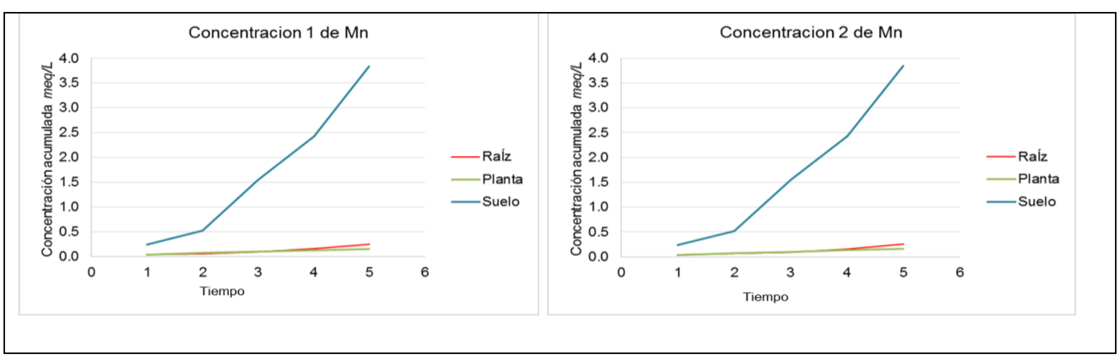


Figure 1. Concentrations of Cu.



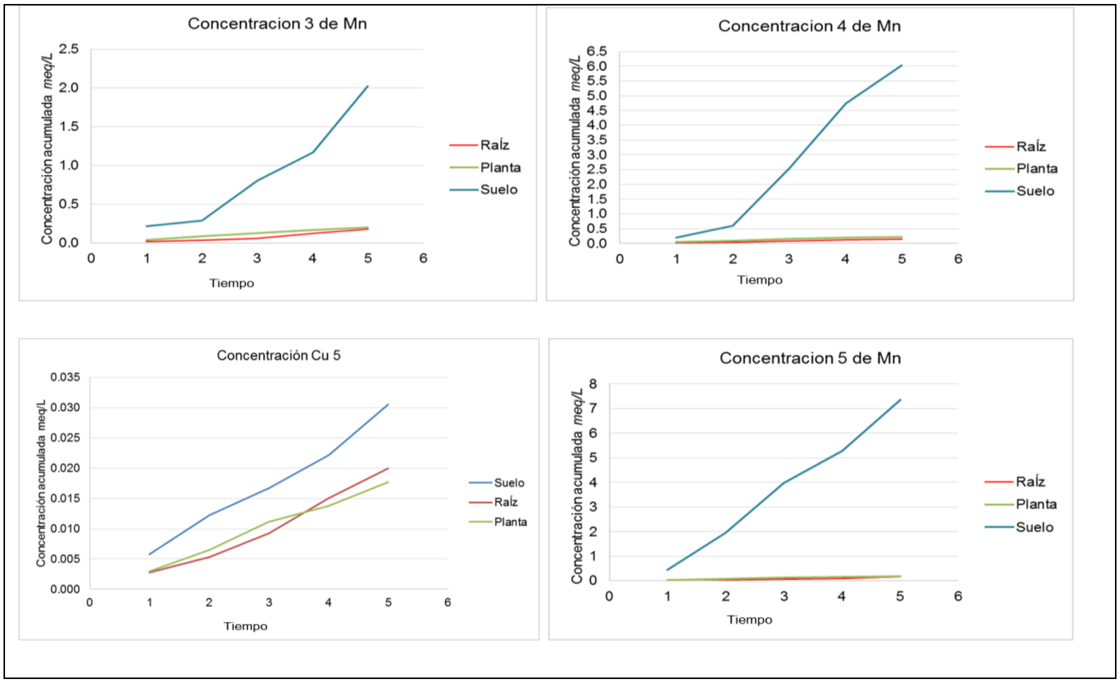
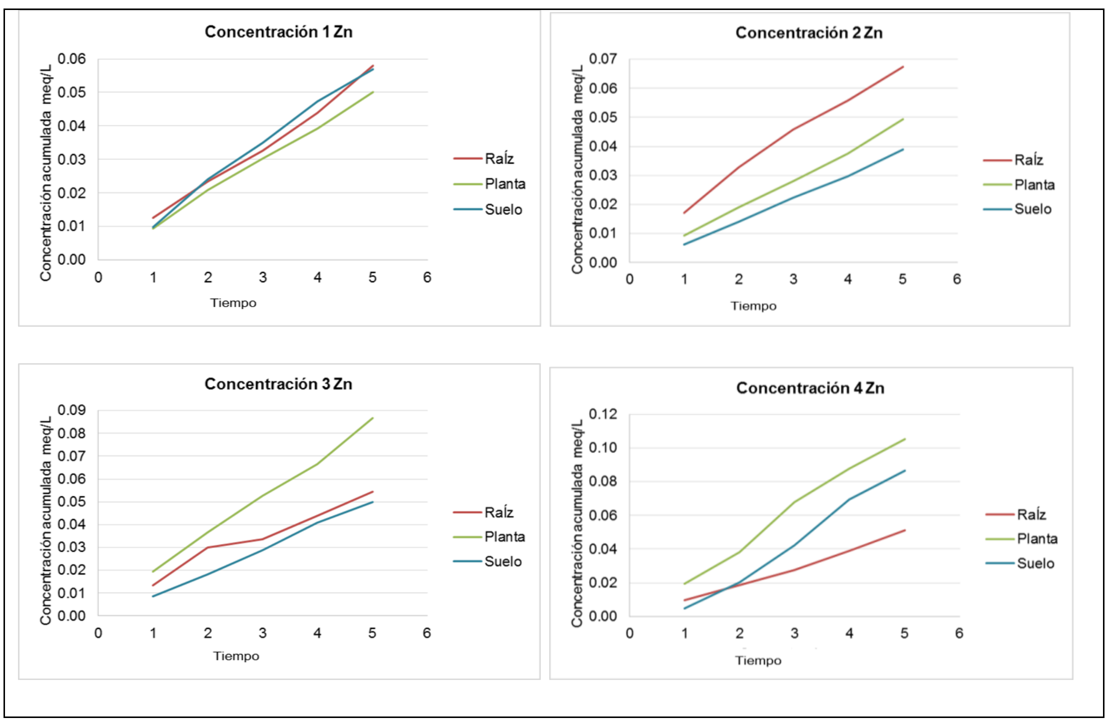


Figure 2. Concentrations of Mn.



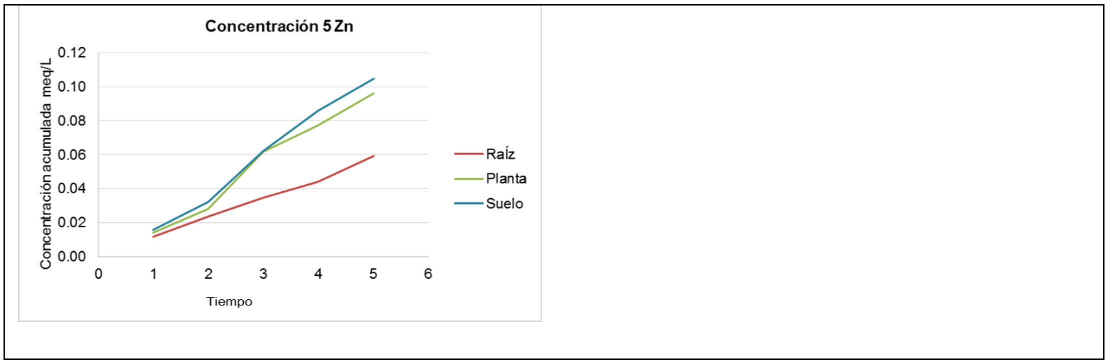


Figure 3. Concentrations of Zn.

In this case it said graphical representation corresponds to equation 1; as observed in all cases there is a process of accumulation of contaminants, regardless of) the element (soil, root or plant), and b) the concentration of the contaminant. For the particular case of copper, the ability to grasp is similar both numerically and functionally in all three cases (soil-plant-root); in the case of manganese, it is mainly fixed on the ground, while the plant roots and having a low retention capacity. Finally, for the case of zinc it has a behavior similar to that of copper.

To determine rates of migration from the equation 2 shows the Figure 4.

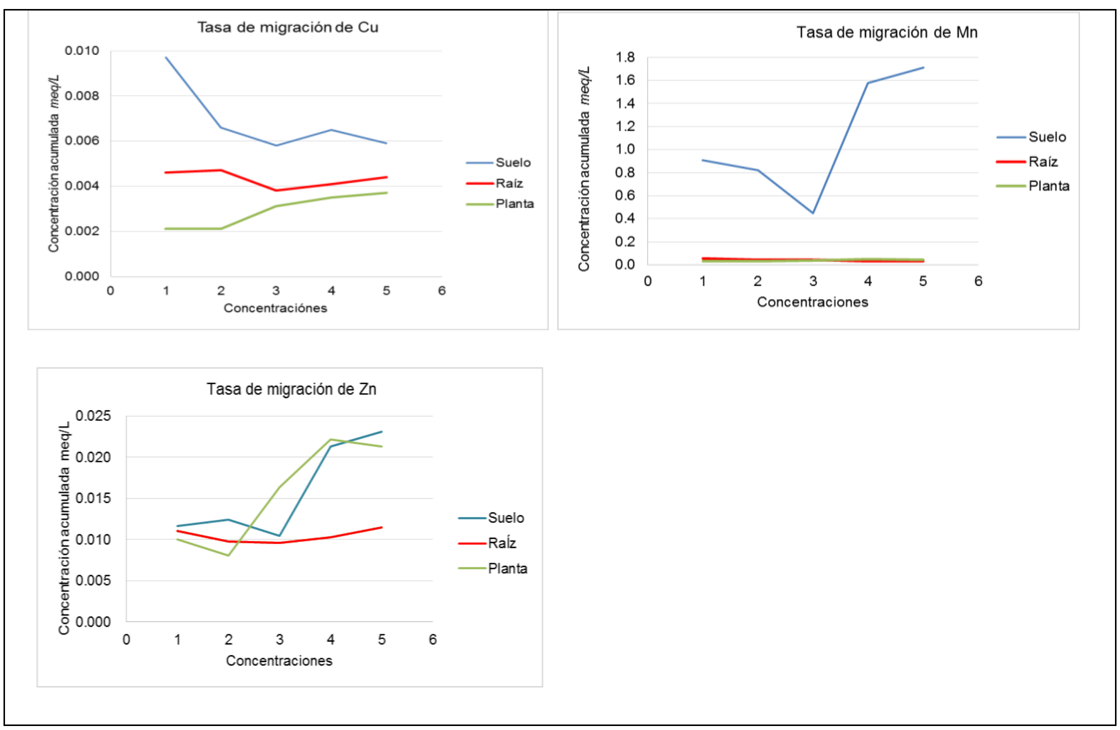


Figure 4. Concentrations of Cu, Mn and Zn.

In this case it shows that the time for copper as it progresses, is diminishing the ability to retain the pollutant on the ground, until it reaches a point of stabilization (asymptote), indicating that the soil has been saturated , that is: no longer has more storage capacity. For the root, it remains constant over time, indicating that the contaminant does not look at the root, but passes by; to see that there plant growth in -very leve- holding capacity, optionally also reaches an asymptotic value.

For manganese is noted that there is a capacity for incremental fixation; single floor, the root and the plant does not work in this case.

In the case of zinc, we note that it is the ground which is again the most active in setting the contaminant: exhibits behavior upward, allowing infer that is not saturated. On the behavior of root, we noticed a steady, indicating that this element does not make fixing polluting behavior. Finally, it presents a behavior first upward, indicating that it is absorbing, but when it comes to a point of stabilization indicates that it has been saturated.

CONCLUSIONS

Through this study it was possible to determine the rates of fixation of heavy metals copper, manganese and zinc.

The process of accumulation of pollutants according to equation [1] indicates that the soil accumulates the largest amount in terms of volume (retained) as rate; this is explained under the concept of CIC, where the threshold value of the land the experiment is 8525 meq / L. From a linear accumulation of cations added by successive irrigations, we have a total of 6.14 mEq / L, much lower than the saturation point of the soil, so it can continue to absorb manganese and zinc. An additional element of the phenomenon is that these two elements are part of the so-called terrestrial minerals, so their mobility in soils is more "easy". By contrast, in the case of copper, being a much denser molecule and higher than that of terrestrial minerals cationic availability, faster pervades.

Accumulation in root, as noted in the graphic in the three cases, is constant and low for all three pollutants, indicating that the rate of contaminant left the ground just go through the root in their migration to the plant.

In the case of accumulation in plant, we see that in copper and manganese behave similarly in the root, and has the highest zinc accumulation in the plant.

According to equation [2], in migration rates for the three pollutants have the root and the plant have a finite capacity and constant magnitude of migration, ie letting in a constant amount of pollutant, regardless degree of concentration applied in irrigation, and that is the stage floor which responds to this variable, accumulating until saturation.

Therefore, the actual risks to water with waste water containing heavy metals is the damage to the soil in the case of Mn, as in the experiment exceeds the Regulations at 32.7%. The floor, once it reaches saturation CIC =, you can no longer hold more contaminants and enter into phase salinization, and if the surplus will be drained by surface runoff or deep percolation.

Thus, in this study it was determined that the impact of irrigating crops with sewage to human well-being is zero, but in the case of impacts to the environment is serious if we consider that the floor is part of the environment, its salinization causes partial or total loss of agricultural land, and turn that loss impacts the food and economic environment of the human being.

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