INNSPUB

International Journal of Agronomy and Agricultural Research (IJAAR)
ISSN: 2223-7054 (Print) 2225-3610 (Online)
http://www.innspub.net
Vol. 3, No. 11, p. 7-15, 2013

RESEARCH PAPER OPEN ACCESS

Assessment of water quality of drains from irrigation district in a semiarid agricultural zone

Dioselina Alvarez-Bernal*, Salvador Ochoa-Estrada, Miriam Arroyo-Damian, Héctor Rene Buelna-Osben, Rodrigo Moncayo-Estrada, Miguel Mora

Centro Interdisciplinario de Investigación parael Desarrollo Integral Regional del IPN, unidad Michoacán, Justo Sierra 28, Centro. C.P. 59510, Jiquilpan, Michoacan, Mexico

Article published on November 27, 2013

Key words: wastewater, water reuse, salinity, agriculture, drainage.

Abstract

Worldwide wastewater is used for agriculture, because of water scarcity. Also, there are increasingly fewer sources of good quality water because of widespread contamination (Ramirez-Fuentes *et al.*, 2002; Rutkowski *et al.*, 2007, Qadir *et al.*, 2010).Agronomic water quality effects on soil, crops and management; major problem with the use of wastewater are salinity, soil permeability and toxicity (Ayers and Westcott, 1994).Wastewater with a high salt concentration leads to increased soil salinity and reducing the availability of water to the plant and induces a drought condition (osmotic effect), that varies with the plant growth stage (Kirda, 1997). The symptoms in plants exposed to high salt concentration are marginal burn, necrosis and sometimes defoliation. Seed germination is also affected by the presence of salts, mainly sodium, chloride and occasionally boron (George, 2004). On the other hand, some specific ions from wastewater may accumulate in plant and reduce yields. Irrigation district 024 (DDR024) is main source of water for agricultural irrigation in Cienega de Chapala. In this zone there is a high demand of water for irrigation; 46,743 ha planted with grains and vegetables, and 1,722 thousands of m3 from drains are used mainly in dry season (Conagua, 2005), the scarcity of water for this production leads to use drainage water (Sandoval and Ochoa, 2010), which is a risk of human and environmental health, furthermore, the soils irrigated with wastewater in this area have become salty (Silva-García *et al.* 2002) which can lead to low productivity.Water quality is a very important concern both for crop irrigation and for soil. The aim of this study was to characterize the physical and chemical composition of drainage water used for agricultural irrigation and assess the suitability and to review the possible salinization and alkalinization involved when using such water for agriculture.

* **Corresponding Author:** Dioselina Alvarez-Bernal ✉ dalvarezb@ipn.mx

Introduction

Worldwide wastewater is used for agriculture, because of water scarcity. Also, there are increasingly fewer sources of good quality water because of widespread contamination (Ramirez-Fuentes *et al.*, 2002; Rutkowski *et al.,* 2007, Qadir *et al.*, 2010).Agronomic water quality effects on soil, crops and management; major problem with the use of wastewater are salinity, soil permeability and toxicity (Ayers and Westcot, 1994).Wastewater with a high salt concentration leads to increased soil salinity and reducing the availability of water to the plant and induces a drought condition (osmotic effect), that varies with the plant growth stage (Kirda, 1997). The symptoms in plants exposed to high salt concentration are marginal burn, necrosis and sometimes defoliation. Seed germination is also affected by the presence of salts, mainly sodium, chloride and occasionally boron (George, 2004). On the other hand, some specific ions from wastewater may accumulate in plant and reduce yields. Irrigation district 024 (DDR024) is main source of water for agricultural irrigation in Cienega de Chapala. In this zone there is a high demand of water for irrigation; 46,743 ha planted with grains and vegetables, and 1,722 thousands of m^3 from drains are used mainly in dry season (Conagua, 2005), the scarcity of water for this production leads to use drainage water (Sandoval and Ochoa, 2010), which is a risk of human and environmental health, furthermore, the soils irrigated with wastewater in this area have become salty (Silva-García *et al.* 2002) which can lead to low productivity. Water quality is a very important concern both for crop irrigation and for soil. The aim of this study was to characterize the physical and chemical composition of drainage water used for agricultural irrigation and assess the suitability and to review the possible salinization and alkalinization involved when using such water for agriculture.

Materials and methods

Study area

Irrigation district 024, Cienega de Chapala is localized in the northeast corner in the state of Michoacan, Mexico (19° 53´, 20° 14´ N and 102° 29´, 102° 45´ W), at an altitude of 1522 meters above sea level, with a 48,920 ha of land cover, (6.11% of surface of the state).

The predominant climate is semi-hot humid (García, 1988) with rains in the summer (Chen *et al.*, 2009), with annual media precipitation of 600 to 800 mm. Annual mean temperature varies between 10.4 and 25.4°C.

The study area lies between the towns of Jiquilpan, Sahuayo, Venustiano Carranza, Briseñas, Pajacuarán, Villamar and Ixtlán. The estimated human population in the region is 191,175 people (INEGI, 2010), this area known Cienega de Chapala michoacana is in a range of extreme drought, for this reason, water for agriculture is scarce (Sandoval and Ochoa, 2010), wastewater from surrounding communities go directly to the drains which are used for agricultural irrigation.

Sampling

Ten sites were sampled: two drains confluent with Duero and Lerma rivers; six belong to a drainage system where is included one drain that has municipal wastewater and reuse water from agriculture; and two dams. These dams were sampling with the aim of show the quality of wastewater from drains and rainwater from dams (Fig. 1.)

Fig. 1. Location map of the study area (DDR024), 1.San Cristobal drain, 2.Ballesteros drain, 3.Cumuato

drain, 4.Ibarra drain, 5. Pajacuarán drain, 6. Guaracha drain, 7. Palmita drain, 8. Casa fuerte drain, 9. Guaracha dam, 10. Jaripo dam.

Sampling was performed during the dry season (June 2011). Various parameters were measured including pH, electrical conductivity (EC), chlorides (Cl), carbonates (CO_3), bicarbonates (HCO_3), calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na). Some parameters were measured in the field with a Hydrolab® DataSonde DS5 and others were analyzed and confirmed in the laboratory according standard methods (APHA, 1998). The water samples were transported in a container with ice to the laboratory where they were kept at 4 °C until processed, within a period not exceeding 48 hours.

The following indexes were calculated; sodium percentage (%Na), sodium adsorption ratio (SAR), residual sodium carbonate (RSC), permeability index (PI), effective salinity (ES), magnesium hazard (MH) according to the methods of Ayers and Westcot (1994), Raju *et al.* (2011), and Cortés-Jimenez *et al.* (2009).

Statistical analysis

We compared ten different sample sites using descriptive statistical analysis and cluster and principal component analysis on the structural values of indexes before mentioned. Statistics analysis were performed using the program PC-ORD version 6.0 (McCune and Mefford, 2011).

Results and discussion

The cluster analysis showed three groups mainly defined by the degree of contamination, and an isolated site with the highest values of most variables (Fig.2.).

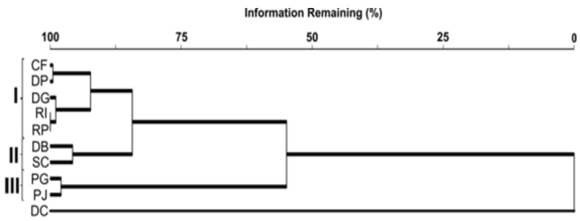

Fig. 2. Dendogram using the beta flexible method (-0.25) and Sorensen distance in the DDR 024.

In the first group a high indexes values defined the sites, including two subgroups one for the drains with reuse water from agriculture and the other, drains with combined wastewater and water from Lerma and Duero Rivers. Such sites presented also high values of several indexes. The second group incorporated drains influenced the Duero River with intermediate values in several variables like HCO_3, Ca, Na, %Na, ES, SAR, and CE. The third group included the dams with the lowest indexes values used as control sites.

The application of PCA analysis to environmental data reveals that the three axes accounted for 92.1% of total variance. The first axis identified the major trend for sites with the highest positive loads of Cl, HCO_3, Na, IP, CE, SAR, ES, and RCS. This axis, accounting for 83.1% of total variance, is interpreted as a representation of "poor water quality" mainly in drains and Lerma river as opposed to lower concentration in dams used as a references (Fig.3.).

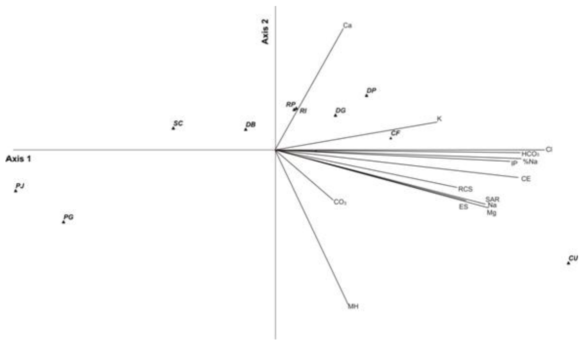

Fig. 3. PCA ordination of sampling stations (italics) and environmental variables vectors, in the DDR 024.

The second axis represented a subordinate trend of sites having high values of Ca and MH and accounted for 9.9% of total variance. This can be interpreted in relation to the hardness of the water within the Lerma river sites and drains with reuse water from agriculture.

Chemical quality

The water quality results for water samples are given in Table 1. The pH of the analyzed varied from 7.1 to 9.2 (Table 1.) to neutral through moderate alkalinity; with a mean of 8.14.

Table 1. Indicators of water quality from samples.

Sampling locations	pH	EC (mSm-1)	Ca^{+2} (meq/L)	Mg^{+2} (meq/L)	K^{+} (meq/L)	Na^{+} (meq/L)	CO_3^- (meq/L)	HCO_3^- (meq/L)	Cl^- (meq/L)	%Na	SAR	RSC	PI	ES	MH
San Cristobal drain	7.8	0.5	2.9	1.5	0	2.1	0.0	3.6	97.7	36.0	1.5	0	36.0	1.2	40.5
Ballesteros drain	7.0	0.6	2.2	2.5	0	2.3	0.0	5.1	216.3	29.6	1.4	0	29.7	1.4	46.3
Cumuato drain	9.2	4.1	2.9	10.5	0.5	43.3	4.0	15.9	595.1	75.7	16.8	6.5	79.8	14.6	78.4
Ibarra drain	8.8	1.0	5.2	2.5	0.5	4.7	1.3	6.2	191.1	36.4	2.4	0	43.4	2.8	32.5
Pajacuarán drain	7.5	1.3	5.8	3.1	0.7	6.5	0.0	10.2	298.0	40.2	3.0	1.2	42.0	3.1	34.8
Guaracha drain	8.4	1.2	5.5	3.1	0.7	6.0	1.1	8.0	223.5	39.3	2.9	0.6	45.1	3.4	36.0
Palmita drain	8.9	1.0	5.2	2.5	0.5	4.4	1.7	5.8	191.6	35.0	2.3	0	43.7	2.6	32.5
Casa fuerte drain	7.1	1.5	4.1	5.2	0.7	6.8	0.0	13	313.5	40.4	3.1	4.0	42.2	1.7	55.9
Guaracha dam	8.8	0.4	2.8	1.9	0.04	1.1	1.0	2.8	22.9	20.2	0.8	0	29.3	0.9	44.18
Jaripo dam	7.8	0.3	3.2	1.4	0	0.8	0.0	3.2	23.9	18.2	0.6	0	18.2	0.9	38.9
Minimum	7.1	0.3	2.2	1.4	0.0	0.8	0.0	2.8	97.7	18.2	0.6	0.0	18.2	0.9	32.5
Máximm	9.2	4.1	5.8	10.5	0.7	43.3	4.0	15.9	595.1	75.7	16.8	6.5	79.8	14.6	78.4
Mean	8.1	1.2	3.8	3.4	0.4	7.8	0.9	7.4	217.4	37.1	3.48	1.2	40.9	3.26	43.9
Standard deviation	0.7	1.09	1.47	2.7	0.31	12.6	1.26	1.4	166.5	15.7	4.8	2.2	16.1	4.09	22.7

An important classification for agriculture irrigation is given for electrical conductivity (EC) and sodium percentage (%Na) (Ayers and Westcot, 1994).

Values for EC vary from 0.3 to 4.1, with an average of 1.19 (Table 1.). Dams have the most low values; high values belong to drains that receive municipal wastewater and agriculture reuse water; and intermediates values correspond to the drains combined with municipal wastewater and waters from rivers Duero and Lerma. Despite, rivers Duero and Lerma also have high salinity due to these rivers receive municipal and industrial wastewater (Pimentel-Equihua, 2008).

A high value of EC indicates a high salt content, so this results in loss of soil productivity and contamination of groundwater (Silva-García *et al.* 2006).

Salinity conditions limit the irrigation with these waters at the germination stage; therefore, the option is to cultivate plants that are salt-tolerant, hence the importance of classification of both irrigation water and soil, to determinate the appropriate use.

Sodium percentage is another parameter that classifies water for irrigation, because sodium reacts with soil and excess Na affects the permeability of the soil, and aeration (Wilcox, 1948), reduce water disposal by osmotic processes. Also sodium excess is toxic for plants; combined sodium with carbonates results in alkaline soils, and when combined with chlorine ion results in saline soils.

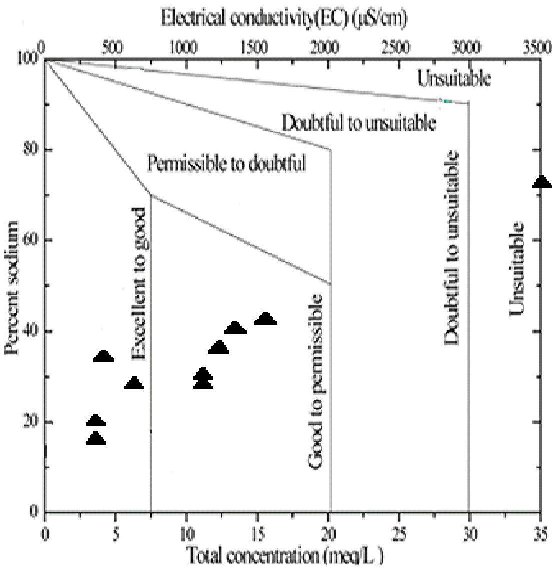

Fig. 4. Wilcox Diagram for plot sodium percent versus electrical conductance.

Sodium percentage has a range between 18.2 a 75.7, with a mean of 37.1 (Table 1.); high values of sodium percentage correspond to drains which combine municipal wastewater and agriculture wastewater. Medium values are the drains influencing rivers waters and low values are from dams. The values for sodium percent and EC were plotted in Wilcox graph (1948) linking these parameters (Fig.4.), 50% of samples fall in the category excellent to good, 40% in permissible to doubtful, only 10% in unsuitable, most of the water from drains and dams can be used for irrigation, without risk of alkalinity, according this classification.

Salinity and alkalinity hazard

Soluble salts in irrigation water can result in saline soils, high concentrations of sodium to alkaline soils. These problems affect mainly arid and semiarid areas, in regions with high water evaporation and poor drainage soils, salts affects soil and plants.

Determination of salinity and alkalinity hazard is determined by absolute and relative concentration of cations, is expressed as sodium adsorption ratio (SAR).

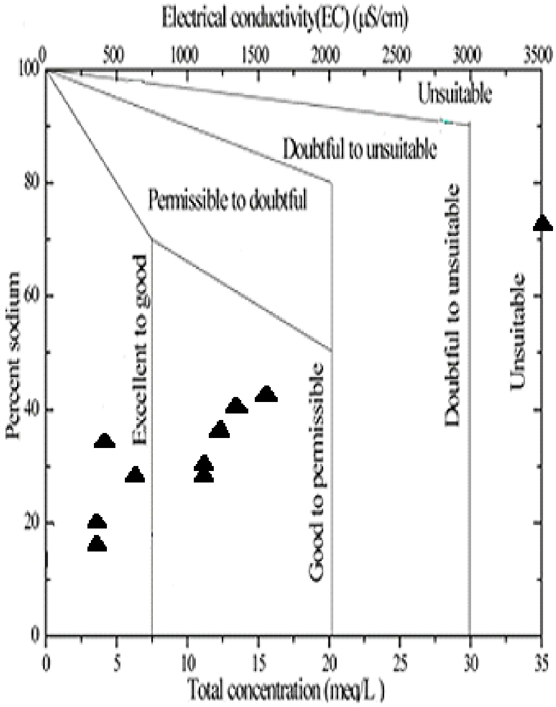

Fig. 5. U.S. Diagram for classification of salinity and alkalinity hazards.

SAR relates to the sodium adsorbed on the soils. The cation exchange complex may become saturated with sodium. If irrigation water is high in sodium and low in calcium this damages the soil structure especially if soil is clay, due to dispersion of the clay (Raju *et al.*, 2011). SAR values of samples varied between 0.6 to 16.75, with a mean of 3.45 (Table 1.), the plot of data on the US salinity diagram is useful for classify irrigation waters, in the X-axis EC is taken as a salinity hazard, in Y-axis SAR as alkalinity hazard (Fig.5.), according to this diagram 50% of samples fall in the category C3S1, these samples shows a high salinity hazard and low alkalinity hazard, continuous use of this kind of irrigation water can lead salinity soils. 40% fall in the category C2S1, indicating moderate salinity hazard and low alkalinity hazard. Water from drains and dams can be used to irrigate crops in this area, without having a negative impact; 10% of samples fall in the category C2S3, indicating that there is a high alkalinity hazard and moderate salinity hazard. This type of water should be used with precaution in agriculture because there is a risk for the soil to become highly alkaline and not productive afterwards. Its use could be restricted to tolerant plants or alkalinity tolerant crops and well drained soils.

Residual sodium carbonate (RSC)

Another important parameter to assess the quality of irrigation water is residual sodium carbonate (RSC). Excess of carbonates or bicarbonates influences adsorption of sodium in the soil (Eaton, 1950).

Precipitation of calcium and magnesium can occur if the sum of carbonates and bicarbonates is in excess.
The range of minimum and maximum values of RSC in the samples are 0 and 6.45 respectively and the mean is 1.22 (Table 1.), the irrigation water in regard to RSC high values of 5meq L-1 consider harmful for plant grow, RSC values of 1.25 to 2.5 meq L-1 are considered marginally suitable and values <1.25 5 meq L-1 are classified as safe. In this study 80% of samples are safe for irrigation, no risk of alkalinity of soil or plant growth; 10% classify as marginally suitable and the rest as harmful.

Permeability index (PI)

When using saline and alkaline waters for an extended period of time they may be affected by soil, permeability index is affected by the content of carbonate, bicarbonate, sodium, calcium, magnesium and chlorine content in soil.

Values of PI varies 18.2 to 79.8, with an average of 40.94 (Table 1.) 40% of samples belong Class I, 50% Class II and 10% Class II but 75% of maximum permeability (Fig.6).

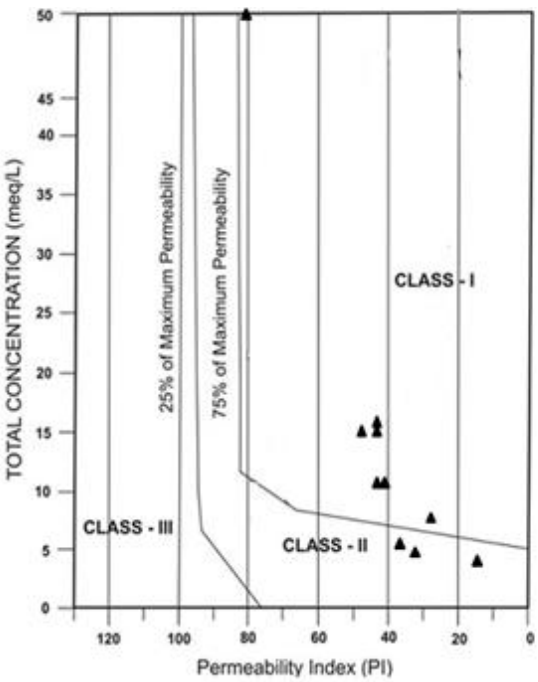

Fig. 6. Classification of irrigation water based on the permeability index.

Effective salinity (ES)

Effective salinity refers to the amount of salts that may be precipitated on the soil due to the more soluble salts in irrigation water. This index considers that when carbonates of calcium, magnesium and calcium sulfates are removed, these tend to rush at the time irrigation water and increases concentration of other salts of soil solution which results in physical and chemical changes in soil. Doneen in 1964 proposed this index and classify as good < 3, conditioned 3 to 15 and not recommended > 15.
The mean value of ES is 3.25, minimum value of 0.9, maximum value 14.6 (Table 1); according to this classification, 70% of samples were classified as good or suitable for irrigation, 20% conditioned and 10% unsuitable for irrigation.

Magnesium hazard (MH)

There must be a balance between calcium and magnesium in water used for irrigation, because magnesium ions are associated with low infiltration rate and poor soil hydraulic conductivity. For plants Mg is essential for growth, however, in excess may cause chlorosis, K deficiency and retarded in growth (Vyshpolsky *et al.*, 2010). A value of MH > 50 is considered harmful and not suitable for irrigation (Zaboles and Darab, 1964).

Values of MH varies 32.46 to 78.35, with a mean of 43.99 (Table 1.), only 20% of the samples are not suitable for irrigation in this index, most of the water from drains and dams does not present a risk, in terms of Mg.

Water demand for agriculture has increased. Agricultural arid and semi-arid areas use wastewater for productivity. Nevertheless, good water quality for agriculture is important for soil and crops. Most of these waters that are reused are greatly, reduced in quality and quantity (García-Garizábal and Causapé, 2010), the result of reuse of water is salinization and alkalinization of soil and aquifers mainly if does not exist an adequate management. All indexes suggest, that 50% of the samples are suitable for irrigation, 40% are conditioned and 10% not suitable for irrigation.

Recycling wastewater is an alternative in arid and semi-arid zones (Bouri, *et al*., 2008), addition to the high organic matter content of these waters contribute to soil and plant nutrients that benefit (Singh, *et al*., 2012). However, there are risks as salinization and alkalinization of soil. Therefore, in irrigation district 024, Cienega de Chapala, there is low salinity hazard in some areas and moderate in others of long term soil, especially where repeatedly reuse irrigation water (Willardson *et al*., 1997) and where clay soils prevail (Oster and Grattan, 2002).The options for using water from DDR024, is the use of gympsum in soils, salt tolerant crops (Oster, 1994). However, it is important that waters from DDR024 receive primary treatment before use for irrigation.

The quality of water used in the DDR024 is suitable for irrigation in most drains, except in Cumuato drain, which it is unsuitable because it is heavily polluted. Besides that, Cumuato reuses this polluted water, and this result in a reduction of quality water. In arid and semiarid areas is still a good option to use drainage water. However, it is convenient to carry out proper management of irrigation water from this point, to avoid problems of salinization and alkalinization of soils and aquifers.

Aknowledgements
We thanks to Alicia Ochoa for technical assistant, Irrigation district 024 for information and TAMU-CONACYT for grand aided support.

References

APHA. 1998. Standard methods for the examination of water and wastewater, **20th** ed. American Public Association, Washington DC.

Ayers RS, Westcot DW. 1994. Water quality for agriculture. Water quality for agriculture. Irrigation and Drainage Paper **29**, FAO, Rome, Italy.

Bouri S, Abida H, Khanfir H. 2008. Impacts of wastewater irrigation in arid and semi-arid regions: case of Sidi Abid región, Tunisia. Environmental Geology, **53**, 1421-1432.

Chen X, Wo F, Chen C, Fang K. 2009. Seasonal changes in the concentrations of nitrogen and phosphorus in farmland drainage and groundwater of the Taihu Lake region of China. Environmental and Monitoring Assessment, **169**, 159-168.

Conagua (Comisión Nacional del Agua) 2005. Plan director para la modernización integral del riego en el Distrito de Riego 024 Ciénega de Chapala, Conagua, México.

Cortés-Jiménez JM, Troyo-Dieguez E, Murillo-Amador B, García-Hernández JL, Garatuza-Doneen LD. 1964. Notes on water quality in agriculture. Water science and engineering paper 4001. Department of water Sciences and Engineering, University of California, California.

Eaton FM. 1950. Significance of carbonates in irrigation waters. Soil Science **339**, 123-133.

García E. 1988. Modificaciones al sistema de clasificación climática de Köppen. Universidad Autónoma de México, México, D.F., México

García-Garizábal I, Causapé J. 2010. Influence of irrigation water management on the quantity and quality of irrigation return flows. Journal of Hydrology **385**, 36-43

George PR. 2004. Agricultural Water Quality Criteria Irrigation Aspects. Resource Management Technical Report No 30. Department of Agriculture Western Australia.

INEGI. 2010. Censo de Población y Vivienda. Instituto Nacional de Estadística Geografía e Informática, México. Retrieved January 11, 2012.

Kirda C. 1997. Assessment of irrigation water quality. Options Méditerranéennes **31**, 367-377.

McCune B, Mefford MJ. 2011. PC-ORD. Multivariate analysis of ecological data, Version 6.0. MjM Software Design. Glenedon Beach, Oregon.

Oster J.D. 1994. Irrigation with poor quality water. Agricultural Water Management **25**, 271-297.

Oster JD, Grattan SR. 2002. Drainage water reuse. Irrigation and Drainage Systems **16**, 297-310.

Pimentel-Equihua JL. 2008. Impacto socioeconómico de las aguas superficiales y subterráneas en la cuenca del río Duero y su importancia en la producción de fresa. SAGARPA, Zamora Michoacán.

Qadir M, Wichels D, Raschid-Sally L, McCornick PG, Drechsel P, Bahri A, Minhas PS. 2010. The challenges of wastewater irrigation in developing countries. Agricultural Water Management **97**, 561-568.

Raju NJ, Shukla UK, Ram P. 2011. Hydrogeochemistry for the assessment of groundwater quality in Varanasi: a fast-urbanizing center in Uttar Pradesh, India. Environmental Monitoring and Assessment **73,** 279-300.

Ramirez-Fuentes E, Lucho-Constantino C, Escamilla-Silva E, Dendooven L. 2002. Characteristics, and carbon and nitrogen dynamics in soil irrigated with wastewater for different lengths of time. Bioresource Technology **85**, 179-187.

Rutkowski T, Raschid-Sally L, Buechler S. 2007. Wastewater irrigation in the developing world-Two case studies from the Kathmandu Valley in Nepal. Agricultural Water Management **88**, 83-91.

Sandoval-Moreno A, Ochoa-Ocaña MA. 2010. Grupos locales, acceso al agua y su problemática de contaminación en la Ciénega de Chapala, Michoacán. Economía, Sociedad y Territorio, **10**, 683-719.

Silva-García JT, Rodríguez C, Ochoa-Estrada S, López S. 2002. Lake Chapala and the cienega aquifer: chemical evidence of their hydraulic communication. Geofísica Internacional **41**, 63-73.

Silva-García JT, Ochoa-Estrada S, Estrada-Godoy F. 2006. Calidad química del agua subterránea de la Ciénega de Chapala como factor de degradación del suelo. Terra, **24**, 503-513.

Singh PK, Deshbhratar PB, Ramteke DS. 2012. Effects of sewage wastewater irrigation on soil properties, crop yield and environment. Agricultural Water Management **103**, 100-104.

Szaboles I., Darab C., 1964. The influence of irrigation water of high sodium carbonate content of soils. In proceedings of 8th international congress of ISSS, Trans, II. 803-812.

Vyshpolsky F, Mukhamedjanov K, Bekbaev U., Ibatullin S, Yudashev T, Noble AD, Mirzabaev A, Aw-Hassan A, Qadir M. 2010. Optimizing the rate and timing of phosphogypsum application to magnesium-affected soils for crop yield and water productivity enhancement. Agricultural Water Management **97,** 1277-1286.

Wilcox LV. 1948. Classification and use of irrigation waters. Washington: US Department of Agriculture, Cir 962.

Willardson LS, Boels D, Smedema LK. 1997. Reuse of drainage water from irrigated areas. Irrigation and Drainage Systems 11, 215-239.