INTERNATIONAL RURAL DEVELOPMENT SYMPOSIUM

PROCEEDINGS

25-27 September 2009

İspir/ERZURUM/TURKEY

CSD
Promoting Civil Society Dialogue

MFİB

Bu proje AB tarafından finanse edilmektedir.
This project is funded by the EU.

Atatürk University
İspir Hamza Polat Vocational School Publication Series: 10

INTERNATIONAL RURAL DEVELOPMENT SYMPOSIUM

25-27 September 2009

İspir/ERZURUM/TURKEY

Publisher
Atatürk University, İspir Hamza Polat Vocational School
25900 İspir, Erzurum-Turkey

EDITORS

Assoc. Prof. Ayhan YILDIRIM

Assis. Prof. Ümmügülsüm ERDOĞAN

Dizayned and Printed in: Mega Ofset, Erzurum

EFFECTS OF FISH AND MUNICIPAL WASTEWATER IRRIGATION ON SOME CHEMICAL PROPERTIES OF SOIL AND CORN (*ZEA MAYS* L.) PLANTS

ASLIHAN ESRİNGÜ[1] ADEM GÜNEŞ[1] NİZAMETTİN ATAOĞLU[1] METİN TURAN[1]
ERTAN YILDIRIM[2]

[1] Atatürk University, Faculty of Agriculture, Department of Soil Science, 25240 Erzurum/Turkey
[2] Atatürk University, Hamza Polat Vocational Training School, 25900, Ispir - Erzurum/Turkey

ABSTRACT: The use of wastewater for irrigation is increasingly being considered as a technical solution to minimize soil degradation and to restore nutrient contents of soils. the aims of this study were to test if wastewater irrigation can increase fertilizer use efficiency and improve soil fertility without affecting the quality of soils and plants. a greenhouse experiment was conducted in 2009 to investigate the effects of irrigation with fish wastewater (fww) and municipal wastewater (mww) on macro and micro nutrient content of soil, yield and mineral contents of maize (*Zea mays* l.) plants grown on a entisol in eastern anatolia, erzurum province, turkey. pot experiments were conducted using a randomized complete block design with two factors (fww and mww), 5 wastewater ratio; fww or mww/ irrigation water (fww or mww 100%: iw 0%; fww or mww 75%: iw 25%; fww or mww 50%: iw 50%; fww or mww 25%: iw 75%; and fww or mww 0%: iw 100%), and five replicates. the studies were done with an ustorthents sampled to a depth of 0-15 cm from agricultural fields in erzurum province (39° 55' n, 41° 61' e) in turkey. plant was harvested 90 d after planting. fish and municipal wastewater irrigation affected significantly soil chemical properties especially in rhizosphere soil and plant nutrient contents after one growing season. application of wastewater increased soil salinity, organic matter, exchangeable Na, K, Ca, Mg, plant available phosphorus and micro elements, and decreased soil pH. wastewater irrigation treatments also increased the yield as well as N, P, K, Ca, Mg, Na, Fe, Mn, Zn, Cu, Pb, Ni and Cd contents of plants. the highest yield, macro and micro nutrient uptake of plants were obtained from the untreated wastewater treatment (control). undesirable side effects such as heavy metal contamination in soil and plant and salinity were not observed with the application of wastewater. it can be concluded that mww can be used confidently in the short term in agricultural land, but fww can be used in sustainable agriculture in the long term both fertilizer source and to increase fertilizer use efficiency.

Key words: heavy metal, plant nutrient contents, soil chemical properties, municipal wastewater irrigation, fish waste wastewater

INTRODUCTION

The continuous growth of world population along with industrial and agricultural activities for increasing the food supply, and consecutive droughts in recent years have caused the consumption of existing water resources to reach their maximum amount in the arid and semi-arid countries. Therefore, demand for water is continuously increasing in arid and semi arid countries. So, water of higher quality is preserved for domestic purpose while that of lower quality is recommended for irrigation. Especially in arid and semi arid countries municipal wastewater is less expensive and considered as an attractive source of irrigation (Al-Rashed and Sherif, 2000; Mohammad and Mazahreh, 2003). Turkey, as a semi-arid country, suffers from shortages in water supply for domestic, industrial, and agricultural purposes. Hence, limited water supplies require careful management for successful agricultural production. In this context, the use of non-conventional water resources, such as treated wastewater must be probed in agriculture and industry (Batarseh et al., 1989).

In many areas of developing countries untreated wastewater flows through channels into rivers where it is diverted by subsistence farmers to small plots of crop grown for nearby urban markets. The public risks of using such contaminated streams for irrigation are obvious. The World Health Organization (WHO, 2004) has recommended that crops to be eaten raw should be irrigated only with biologically treated effluent that has been disinfected to achieve a coli form level of not more than 100 coli form per 100 ml in 80% of the samples. The use of untreated wastewater and water supplies contaminated with sewage for irrigation has been implicated as one of the important sources of pathogenic micro-organism contaminating vegetables (Doyle, 1990; Islam et al., 1990; Wei et al., 1995).

Application of wastewater to cropland and forested lands is an attractive option for disposal because it can improve physical properties and nutrient contents of soils (Sommers, 1977; Pomares et al., 1984). Wastewater irrigation provides water, N and P as well as organic matter to the soils (Siebe, 1998), but there is a concern about the accumulation of potentially toxic elements such as Cd, Cu, Fe, Mn, Pb and Zn from both domestic and industrial sources.

The objectives of this study were to evaluate the fertilizer use efficiency, chemical soil characteristics and possible accumulation of heavy metals in the Entisol, and also to evaluate the yields and nutrient contents of corn in response to irrigation with fish, and municipal wastewater.

MATERIAL AND METHODS

Pot experiments

Pot experiments were conducted using a randomized complete block design with two factors (FWW and MWW), 5 wastewater ratio (the application rates of FWW and MWW diluted with irrigation water (IW) were 100%, 75%, 50%, 25%, and 0%) and five replicates. The studies were done with an Ustorthents (Soil Survey Staff, 1992) sampled to a depth of 0-15 cm from agricultural fields in Erzurum province (39° 55' N, 41° 61' E) in Turkey.

To support optimum plant growth, ammonium nitrate (140 kg N ha^{-1}), triplesuphere phosphate (200 kg P_2O_5 ha^{-1}), and potassium sulphate (500 mg K_2O kg^{-1} ha^{-1}) were applied before planting. Plant had been grown in a heated greenhouse under natural light (14 h day length), a minimum temperature of 10-11°C and maximum of 25-30°C, and a relative humidity of 30-40%. The water content of the soil was maintained at 70% of field capacity (375 g kg^{-1}) throughout the 90 d experiments by daily additions of wastewater. Some chemical properties of the wastewater used for irrigation were determined by the methods described by American Public Health Association (APHA), American Water Works Association (AWWA), and Water Environment Federation (WEF) (1985), and Faecal Coliform (FC) was tested by multiple tube fermentation procedure as described by APHA (1995) (Table 1). Shoots was harvested 90 d after planting and washed with dionized water to remove soil particles and also soil sample for evaluation macro and micro element were taken each of the treatment after plant harvest.

Soil Analysis

Soil samples were air-dried, crushed, and passed through a 2-mm sieve prior to chemical analysis. Cation exchange capacity (CEC) was determined using sodium acetate (buffered at pH 8.2) and ammonium acetate (buffered at pH 7.0) according to Sumner and Miller (1996). The Kjeldahl method (Bremner, 1996) was used to determine organic N while plant-available P was determined by using the sodium bicarbonate method of Olsen et al. (1954). Electrical conductivity (EC) was measured in saturation extracts according to Rhoades (1996). Soil pH was determined in 1:2 extracts, and calcium carbonate concentrations were determined according to McLean (1982). Soil organic matter was determined using the Smith-Weldon method according to Nelson and Sommers (1982). Ammonium acetate buffered at pH 7 (Thomas, 1982) was used to determine exchangeable cations. Micro elements in the soils were determined by Diethylene Triamine Pentaacetic Acid (DTPA) extraction methods (Lindsay and Norvell, 1978). Some physical and chemical properties of soil was given Table 2.

Plant Analysis

Plant samples were oven-dried at 68°C for 48 h and ground to pass 1mm sieve. The Kjeldahl method and a Vapodest 10 Rapid Kjeldahl Distillation Unit (Gerhardt, Konigswinter, Germany) were used to determine total N (Bremner, 1996). Macro- (P, K, S, Ca Mg and Na) and micro-elements (Fe, Mn, Zn, Cu,Pb, Ni and Cd) were determined after wet digestion of dried and ground sub-samples using a HNO_3-H_2O_2 acid mixture (2:3 v/v) with three step (first step; 145°C, 75%RF, 5 min; second step; 180°C, 90%RF, 10 min and third step; 100°C, 40%RF, 10 min) in microwave (Bergof Speedwave Microwave Digestion Equipment MWS-2) (Mertens, 2005a). Tissue P, K, S, Ca, Mg, Na, Fe, Mn, Zn, Cu, Pb, Ni and Cd were determined using an Inductively Couple Plasma spectrophotometer (Perkin-Elmer, Optima 2100 DV, ICP/OES, Shelton, CT 06484-4794, USA) (Mertens, 2005b).

Statistical analysis: All data obtained from the effects of different wastewater irrigation on soil and plant chemical properties in contrast to non-wastewater irrigated in the present study were subjected analysis of variance (ANOVA). The Duncan's multiple range tests were performed for mean comparisons using SAS statistical software (SAS, 1982).

RESULTS AND DISCUSSION

1 Effect of wastewater irrigation on soil properties: Municipal wastewater (MWW) irrigated soils (100%) showed lower pH values and high organic matter N, P, Mg, Cu, Mn, Zn, Pb, N, and Cd compared to FWW irrigated soils with different dilution ratio. This slight pH change can be attributed to the release of exchangeable cations during the mineralization of organic matter (Woomer et al., 1994) (Table 4). As this is entisol soils, decrease of pH can increase the solubility of exchangeable cations. Such decrease in the soil pH

would enhance solubility and availability of nutrients in soils such as phosphorus, and micro element (Mohammad, 1986; Mohammad and Mazahreh, 2003). The salt content of the soils among the treatments increased as a consequence of MWW and FWW irrigation. Values represent an increase in salt content in soils cultivated with 65 -26 fold at 100% ratio, 18- 20 fold at 75% ratio, 16-13 fold at 50% ratio, 7-6 fold at 25% ratio, compared to the control (0%), respectively (Table 3). Other researchers reported similar increases in the salt contents of soils after wastewater irrigation (García and Hernández, 1996; Vázquez Montiel et al., 1996).

The organic matter and total N level of the MWW irrigation soils was higher than that of the FWW irrigated soils. Organic matter and N levels of the soils decreased sharply with diluted irrigation water. Values represent increases in organic matter of MWW and FWW irrigation soil of 86.1-77.2%, 42.3-23.6%, 33.0-22.0%, and 29.2-18.9% in following order 100%, 75%, 50%, and 25% when compared to the control (0%), respectively (Table 3). The N content of the soils showed similarity with organic matter contents. Many investigations, including long and short-term studies, showed that soil fertility increased as a consequence of the application of wastes such as pig slurry, wastewater, sewage sludge, etc. (Bernal et al. 1993; Chakrabarti, 1995; Manicas et al., 1998).

The results also show that the cation exchange capacity (CEC) was higher in the MWW soils than in the FWW soils. When the municipal and fish wastewater was treated to the dilution process, CEC values of the soils decreasing followed the order of 100%>75%>50%>25% in soils. Exchangeable cation contents as Na, K, and Ca increased due to MWW and FWW ratio irrigation rate, and followed the order of 100%>75%>50%>25% in soils. Available P concentrations were large in the MWW soils cultivated with maize plants when compared with FWW and control soils (Table 3), probably due to high organic matter amended with wastewater and increase the fertilizer use efficiency. Other researches found that application of wastewater irrigation resulted in about 4, 10 and 8 fold increases in N, P and, K, respectively, above the recommended fertilizer rates for forage crops (Burns et al., 1985).

Plant total heavy metal concentrations as Fe, Mn, Zn, Cu, Ni, Pb and Cd were less in all soils with treated irrigation water (control) than MWW and FWW treatments. When compared with the control group (0%), results represent a relative increase rate of Cu, Mn, Zn, Pb, Ni, and Cd were about 2.5-1.5 fold for Cu, 2.21-1.6 fold for Mn, 1.7-2.2 fold for Zn, 14-13 fold for Pb, 32-11 fold for Ni, and 14-9 fold for Cd at 100% MWW and FWW irrigation treatment. In general, it seems that heavy metals tend to accumulate in the surface layers of soil (Chang et al., 1984), and that their movement is limited by strong binding with clay minerals and organic matter. Our results were in good agreement with those reported by Al-Lahham et al. (2003), Soumare et al. (2003), Dere et al. (2006), Abbas et al. (2007), and Madrid et al. (2007).

2 Effect of wastewater irrigation on plants yields and mineral content

2.1 Yields: Municipal wastewater and fish wastewater irrigation positively affected maize plant yields. The highest yield of maize plant (230 g plant^{-1}) was obtained from MWW treatments at 100% ratio (Fig. 1). When compared with the control group (0%), results represent a relative increase rate of dry matter for MWW and FWW at the 100%>75%>50%>25% dilution ratio were about 23.2-20.3%, 67.05-45.3%, 91.0-70.5%, and 109.0-88.7%, respectively.

2.2 Macro element (N, P, K, Ca, Mg, Na) contents: Wastewater irrigation had significant effects on plant N, P, K, Ca, Mg and Na contents of maize plants (Fig. 2). 100% ratio treatment had the highest N (2.66g 100 g dw^{-1}), P (0.45 g 100 g dw^{-1}), K (2.0 g 100 g dw^{-1}), Ca (3678 mg kg dw^{-1}), Mg (1682 mg kg dw^{-1}), and Na (450 mg kg dw^{-1}) in MWW irrigation and , N (2.50 g 100 g dw^{-1}), P (0.40 g 100 g dw^{-1}), K (1.99 g 100 g dw^{-1}), Ca (3220 mg kg dw^{-1}), Mg (1388 mg kg dw^{-1}), and Na (430 mg kg dw^{-1}) in FWW irrigation (Fig. 2). Macro element contents of plants decreased when the MWW and FWW ratio irrigation rate was decreased, and followed the order of 100%>75%>50%>25%.

2.3 Heavy metal (Fe, Mn, Zn, Cu, Pb, Ni and Cd) contents: Heavy metal contents of plant were also significantly affected by the MWW and FWW irrigation. 100% ratio of MWW treatment had the highest Fe (177.4 mg kg dw^{-1}), Mn (50.7 mg kg dw^{-1}), Zn (93.7 mg kg dw^{-1}), Cu (8.9 mg kg dw^{-1}), Pb (15.8 mg kg dw^{-1}), Ni (3.25 mg kg dw^{-1}), and Cd (17.6 mg kg dw^{-1}), but Fe (99.8 mg kg dw^{-1}), Mn (42.1 mg kg dw^{-1}), Zn (69.2 mg kg dw^{-1}), and Cu (7.8 mg kg dw^{-1}), Pb (6.9 mg kg dw^{-1}), Ni (0.9 mg kg dw^{-1}), and Cd (3.8 mg kg dw^{-1}) in FWW at 100% ratio treatment (Fig. 3). Our results were in good agreement with those reported by del Arroya et al. (2002), Kızıloğlu et al (2007), Kızıloğlu et al (2008), and Belagziz et al (2008).

CONCLUSIONS

Municipal and fish wastewater irrigation affects the physical, chemical properties and increase the fertilizer use efficiency of the soils, yields and also mineral contents in the plants. Therefore, characteristics of wastewater and soil should be considered in management of wastewater irrigation during the crop production. As compared to control treatment soils, the results revealed that there was a significant decrease in soil pH and there were increases in salt and, organic matter contents in soils, CEC, macro and microelement concentrations in leaves. Therefore, MWW and FWW have a high nutritive value that may improve plant growth, reduce fertilizer application rates; increase fertilizer use efficiency and increase productivity of poor fertility soils, but effects of MWW treatment efficiency on macro and micro nutrient availability for plant uptake were higher than FWW treatments. It is suggested that FWW wastewater can be used to irrigate field crop, with a continuous monitoring of the effluent quality to avoid contamination. Soil degradation in semi-arid environments needs alleviation in order to preserve non-renewable resources. MWW and FWW irrigation can be used as an organic fertilizer to improve the physical, chemical properties and to increase plant arability of macro and micro nutrient of soils in addition to potential source of nutrients. The major disadvantage of the municipal wastewater irrigation is the accumulation of immobile heavy metals in soils.

In fact, our results show that the farmer should take a long-term advantage in municipal wastewater irrigation and at the same time satisfy consumer demands for food safety, but FWW can be use more safely than MWW usage. Meanwhile, in the long term, farmer don't have any questions of soil fertility, reduce heavy metal concentration and protection of food chain, MWW or FWW should be use as diluted with irrigation water. Field studies are needed to further test and quantify the effectiveness of waste water irrigation in enhancing soil fertility and nutrient efficiency.

Table 1. Characteristics of the municipal wastewater (MWW) and fish wastewater (FWW) used for irrigation (Mean ± Standard deviation, n = 10)

Municipal Wastewater				Fish Wastewater			
Parameters	Mean ± Sd	Parameters	Mean ± Sd	Parameters	Mean ± Sd	Parameters	Mean ± Sd
pH	8.35 ± 0.24	Ni, mg l^{-1}	0.10 ± 0.01	pH	7.80 ± 0.12	Ni, mg l^{-1}	0.01±0.001
EC, dS m^{-1}	1.79 ± 0.10	Cd, mg l^{-1}	0.13 ± 0.02	EC, dS m^{-1}	1.20 ± 0.10	Cd, mg l^{-1}	0.08 ± 0.02
TDS, mg l^{-1}	1143 ± 105	Mn, mg l^{-1}	0.29 ± 0.01	TDS, mg l^{-1}	770.8 ± 40	Mn, mg l^{-1}	0.11 ± 0.01
SS, mg l^{-1}	128 ± 14	Zn, mg l^{-1}	0.40 + 0.05	SS, mg l^{-1}	100 ± 16	Zn, mg l^{-1}	0.12 ± 0.05
Total N, mg l^{-1}	1402 ± 135	Fe, mg l^{-1}	0.30 ± 0.01	Total N, mg l^{-1}	1100 ± 110	Fe, mg l^{-1}	0.14 ± 0.01
P, mg l^{-1}	6.20 ± 0.13	Pb, mg l^{-1}	0.10± 0.01	P, mg l^{-1}	5.00 ± 0.10	Pb, mg l^{-1}	0.01±0.001
CO_3, mg l^{-1}	2.00 ± 0.11	Ca, mg l^{-1}	50 ± 1.13	CO_3, mg l^{-1}	1.90 ± 0.10	Ca, mg l^{-1}	40 ± 1.00
HCO_3, mg l^{-1}	7.00 ± 0.65	Mg, mg l^{-1}	41 ± 0.86	HCO_3, mg l^{-1}	7.00 ± 0.40	Mg, mg l^{-1}	33 ± 0.34
$CaCO_3$, mg l^{-1}	0.11 ± 0.01	Na, mg l^{-1}	196 ± 20	$CaCO_3$, mg l^{-1}	0.10 ± 0.01	Na, mg l^{-1}	150 ± 21
S, mg l^{-1}	3.00 ± 0.04	K, mg l^{-1}	55 ± 0.71	S, mg l^{-1}	2.10 ± 0.05	K, mg l^{-1}	40 ± 0.91
Cl, mg l^{-1}	7.00 ± 0.50	SAR	6.25 ± 0.28	Cl, mg l^{-1}	5.50 ± 0.20	SAR	4.12 ± 0.43
Cu, mg l^{-1}	0.28 ± 0.02	FC, cfu 100 ml^{-1}	3719 ± 14	Cu, mg l^{-1}	0.10 ± 0.02	FC, cfu / 100 ml	870± 9

TDS: Total Dissolved Salts, SS: Suspended Solids, SAR: Sodium Adsorption Ratio, FC: Faecal Coliform

Table 2. .Chemical properties of experimental field soils before planting (Mean ± Standard deviation, n = 10)

Soil properties	**0-30**
Cation exchangeable capacity (CEC), cmol$_c$ kg^{-1}	24.00±1.85
Total N, %	0.10±0.03
pH (1:2 soil:water)	7.35± 0.16
Organic matter, %	1.40±0.09
$CaCO_3$, %	1.30±0.08
Plant available P, mg kg^{-1}	8.00±1.90
Exchangeable Ca, cmol$_c$ kg^{-1}	22.50±2.40
Exchangeable Mg, cmol$_c$ kg^{-1}	8.00±0.50
Exchangeable K, cmol$_c$ kg^{-1}	2.20±0.80
Exchangeable Na, cmol$_c$ kg^{-1}	0.20±0.02
Available Fe, mg kg^{-1}	3.05±0.15
Available Mn, mg kg^{-1}	1.62±0.08
Available Zn, mg kg^{-1}	1.50±0.10
Available Cu, mg kg^{-1}	1.20±0.11
Available B, mg kg^{-1}	0.33±0.07
Available Ni, mg kg^{-1}	0.08±0.01
Available Pb, mg kg^{-1}	0.10±0.02
Available Cd, mg kg^{-1}	0.11±0.04
EC, dS m^{-1}	1.15±0.03

Table 3. Chemical properties of the rhizosphere area of irrigated with municipal wastewater and fish wastewater after the harvest of maize plant

Parameters	Municipal Wastewater					Fish Wastewater				
	0	25%	50%	75%	100%	0	25%	50%	75%	100%
pH,(1:2 soil:water)	7.95 a	7.36 b	6.95 c	6.05 d	5.95 d	7.95 a	7.85 b	7.19 c	7.00 c	6.22 d
Salt content , %	0.01 c	0.07 c	0.16 b	0.18 b	0.65 a	0.01 d	0.06 d	0.13 c	0.20 b	0.26 a
Organic matter, %	1.30 c	1.68 b	1.73 b	1.85 b	2.42 a	1.27 c	1.51 b	1.55 b	1.57 b	2.25 a
$CaCO_3$, %	1.10 a	0.89b	0.51b	0.55b	0.73 b	1.12 a	0.95 b	0.79 b	0.61bc	0.42 c
N,%	0.01 c	0.06 b	0.06 b	0.06 b	0.08a	0.01 c	0.05 b	0.05 b	0.07 a	0.08 a
P, mg kg^{-1}	8.19 c	12.44 b	10.95 b	13.31 b	17.26 a	8.20 b	9.45 ab	10.19 a	10.14 a	12.00 a
CEC, cmol$_c$ kg^{-1}	25.00 c	26.29 bc	28.86 b	29.13 b	32.73 a	25.89 b	25.29 b	26.86 ab	27.13 a	29.73 a
K, cmol$_c$ kg^{-1}	2.08 b	2.70 b	2.81 b	3.00 ab	3.50 a	2.40 b	2.50 ab	2.64 a	2.79 a	2.85 a
Ca, cmol$_c$ kg^{-1}	18.43 b	19.63 b	20.06 ab	23.42 a	24.11 a	18.47 a	18.67 a	19.30 a	19.91 a	19.21 a
Mg, cmol$_c$ kg^{-1}	3.93 c	4.68b	4.73 b	4.78 ab	4.89 a	3.68 b	3.89 ab	3.95 a	4.00 a	4.10 a
Na, cmol$_c$ kg^{-1}	0.13 c	0.18 b	0.18 b	0.21 b	0.39 a	0.04 d	0.24 c	0.33 c	0.41 b	0.58 a
Fe, mg kg^{-1}	3.02 a	3.13 a	3.15 a	3.18 a	3.26 a	3.03 a	3.10 a	3.18 a	3.22 a	3.26 a
Cu, mg kg^{-1}	1.36 c	2.02 b	2.07 b	2.22 b	3.42 a	1.27 c	1.64 b	1.72 b	1.92 a	2.05 a
Mn, mg kg^{-1}	1.46 c	1.62 c	1.96 c	2.37 b	3.23 a	1.40 c	1.61 b	1.79 b	2.00 a	2.21 a
Zn, mg kg^{-1}	1.29 b	1.32 b	1.49 b	1.63 b	2.21 a	1.31 c	1.64 b	1.72 b	1.81 b	2.86 a
Pb, mg kg^{-1}	ND	0.07 b	0.07 b	0.09 b	0.14 a	ND	ND	ND	0.01 b	0.13 a
Ni, mg kg^{-1}	ND	0.01 b	0.12 b	0.17 b	0.32 a	ND	ND	ND	0.03 b	0.11 a
Cd, mg kg^{-1}	ND	0.01 b	0.07 b	0.09 b	0.14 a	ND	ND	ND	0.05 b	0.09 a

Means with different letters within rows are significantly different ($p<0.05$), ND: Non Detectable

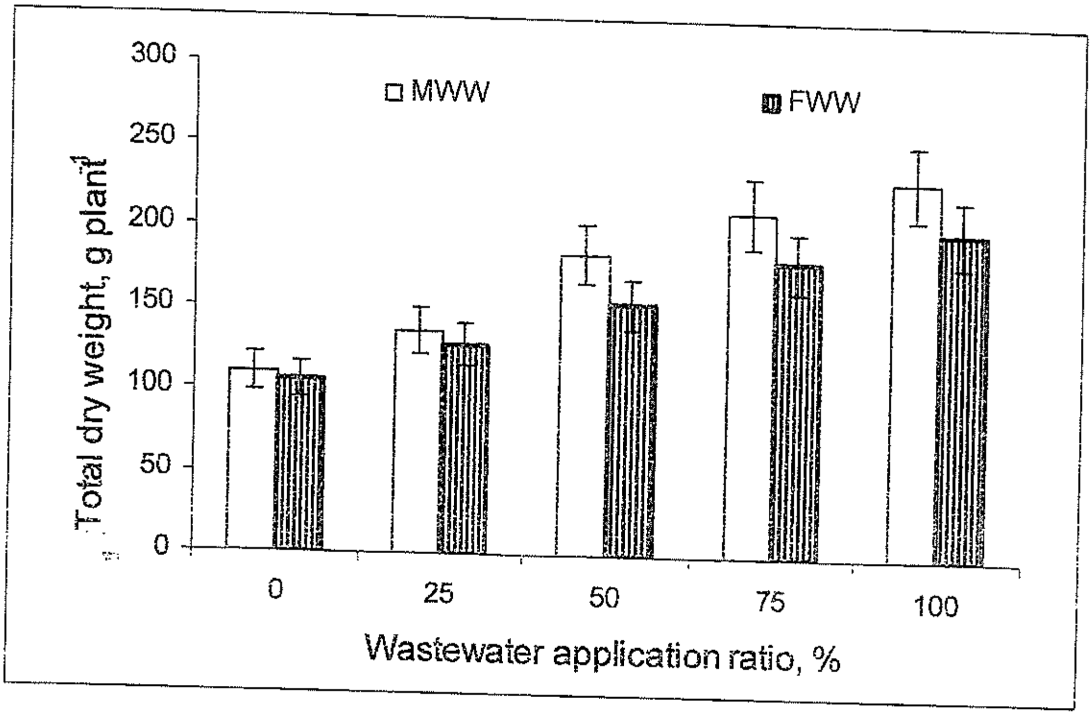
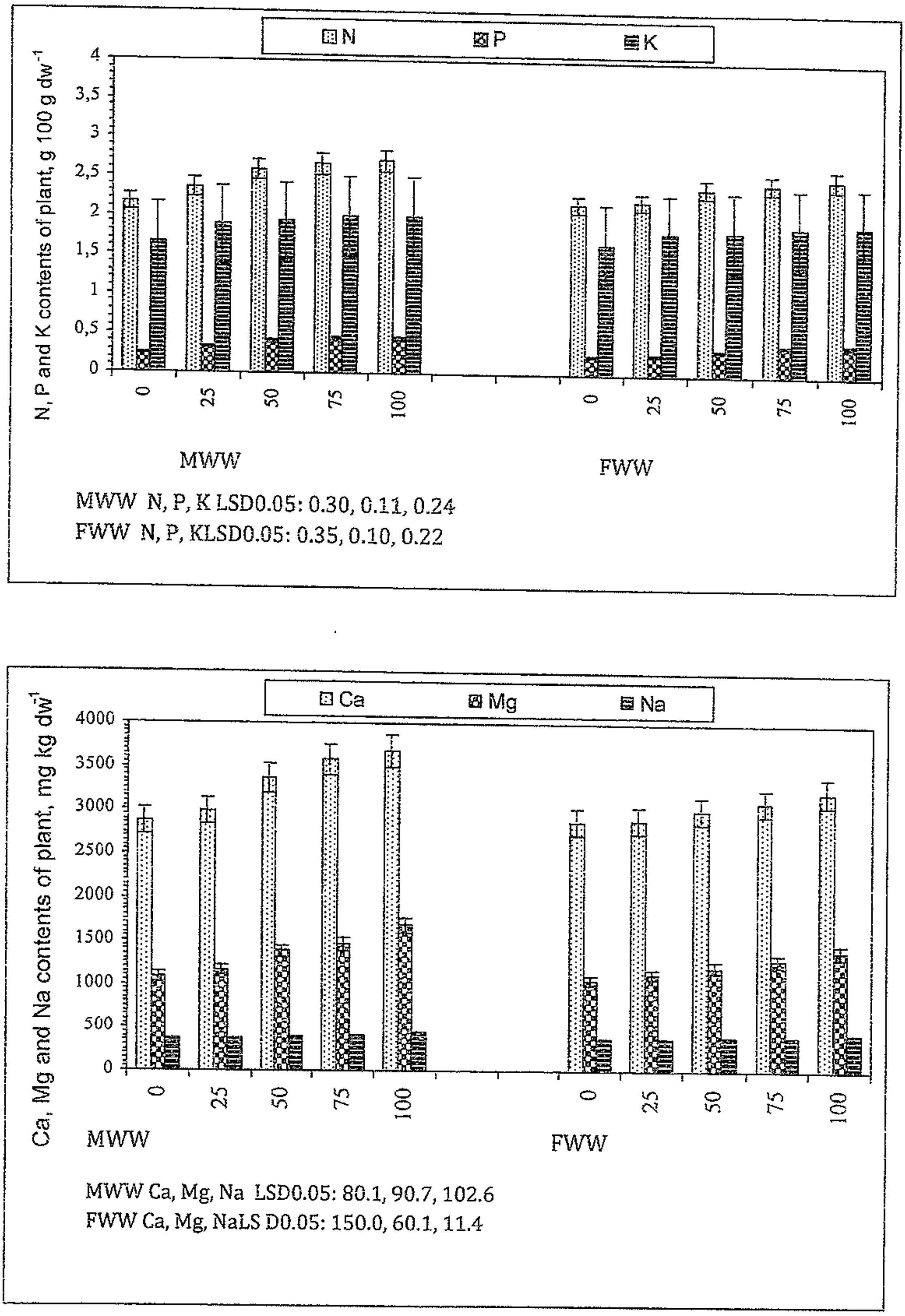


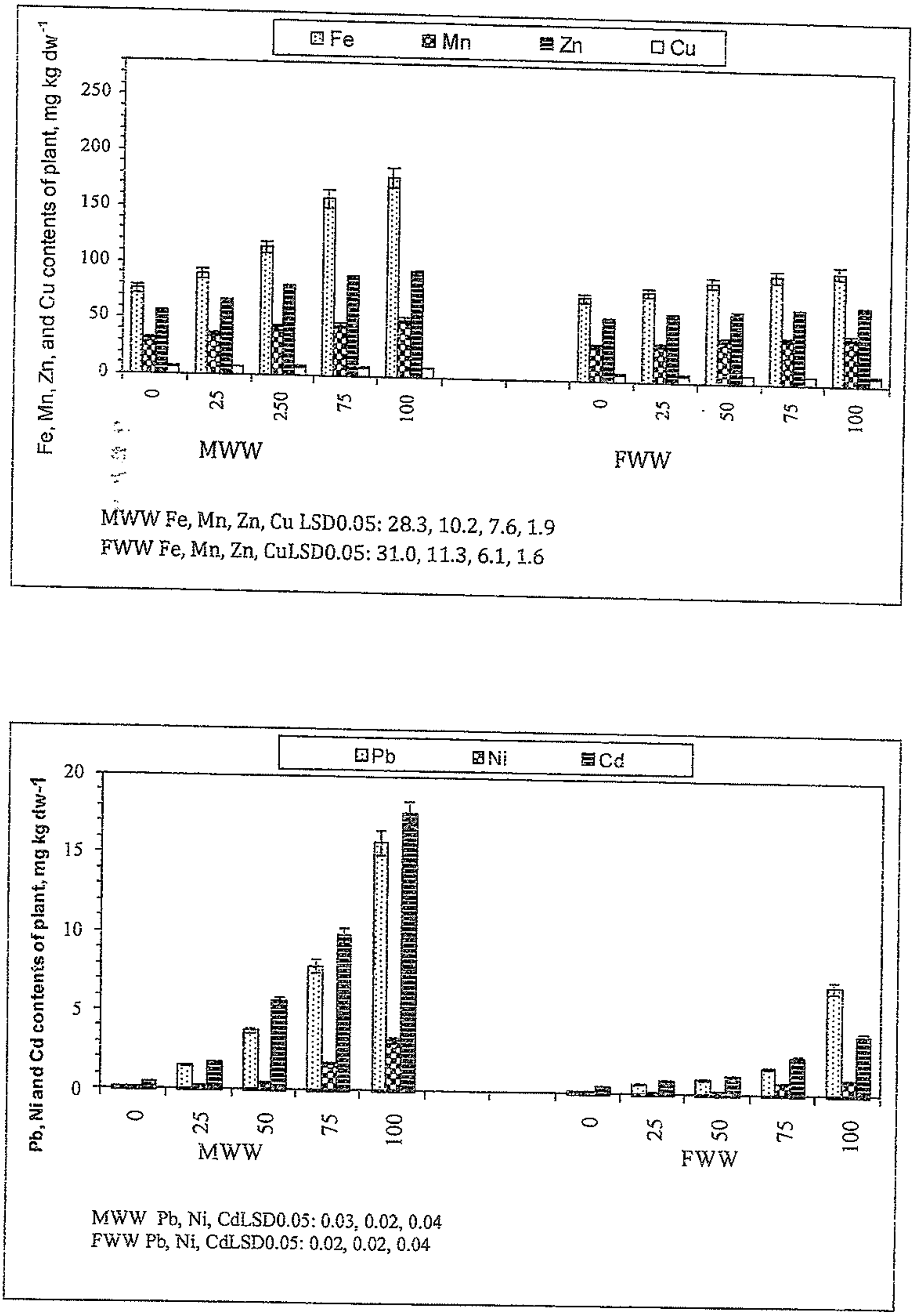
Figure 1. Effects of MWW and FWW irrigation treatments on yields of maize plants.



MWW N, P, K LSD0.05: 0.30, 0.11, 0.24
FWW N, P, KLSD0.05: 0.35, 0.10, 0.22

MWW Ca, Mg, Na LSD0.05: 80.1, 90.7, 102.6
FWW Ca, Mg, NaLS D0.05: 150.0, 60.1, 11.4

Figure 2. Effects of different MWW and FWW irrigation treatments N, P, K, Ca, Mg and Na contents of maize plants



MWW Fe, Mn, Zn, Cu LSD0.05: 28.3, 10.2, 7.6, 1.9
FWW Fe, Mn, Zn, CuLSD0.05: 31.0, 11.3, 6.1, 1.6

MWW Pb, Ni, CdLSD0.05: 0.03, 0.02, 0.04
FWW Pb, Ni, CdLSD0.05: 0.02, 0.02, 0.04

Figure 3. Effects of different MWW and FWW irrigation treatments Fe, Mn, Zn, Cu, Pb, Ni, and Cd contents of maize plants

REFERENCES

Abbas S.T., Sarfraz M., Mehdi S.M., Hassan G., Ur-Rehman O. 2007. Trace elements accumulation in soil and rice plants irrigated with the contaminated water. Soil and Tillage Research, 94, 503-509.

Al-Lahhman O., Assi N.M., Fayyad, M., 2003. Impact of treated wastewater irrigation on quality attributes and contamination of tomato fruit. Agriculture Water Management, 61, 51-62.

Al-Rashed M.F., Sherif M.M. 2000. Water resources in the GCC countries: an overview. Water Resour. Manag. 14, 59-75.

APHA 1995. Standard Methods for the Examination of Water and Wastewater. American Public Health Association. 19th Edition. American Public Health Association, Washington, DC.

APHA, AWWA, WEF, 1985. Standard Methods for the Examination of Water and Wastewater. In: Greenberg, A.E., Trussell, R.R., Clesceri, L.S., (Eds.). American Public Health Association, American Water Works Association, Water Environment Federation, Washington, DC.

Arroya M., M.D, Cots M.A.P., Hornedo R.M.I, Rodriguez E.M.B., Beringola L.B., Sanchez J.V.M. 2002. Sewage sludge compost fertilizer on maize yiled and soil heavy metal concentration. Rev. Int. Contam. Ambient, 18,147-150.

Batarseh L.I.,.Rimavi O.A., Salameh E. 1989. Treated wastewater reuse in agriculture. Part I. Hussein Medical Center Project. Bulletion of Water Research and Study Center, University of Jordan, Jordan. Bulletion No:12.

Bernal M.P., Roig A., Garcia D. 1993. Nutrient balances in calcareous soils after application of different rates of pig slurry. Soil Use and Management, 9, 9-14.

Bremner J.M. 1996. Nitrogen-Total. In: Sparks, D.L. (Ed.), Methods of Soil Analysis, Part 3, Chemical Methods. SSSA Book Set: 5, Soil Science Society of America, Madison, WI, pp. 1085-1121.

Burns J.C., Westerman P.W., King L.D., Cummings G.A., Overcash M.R., Goode L. 1985. Swine lagoon effluent applied to Coastal Bermudagrass. 1. Forage yield, quality and element removal. J. Environ. Qual., 14, 9-14.

Chakrabarti C. 1995. Residual effects of long-term land application of domestic wastewater. Environment International, 21, 333-339.

Dere C., Lamy I., Jaulin A., Cornu,S. 2006. Long-term fate of exogenous metals in sandy Luvisol subjected to intensive irrigation with raw wastewater. Environmental Pollution, 145, 31-40.

Doyle M.P. 1990. Food borne illness: Pathogenic *E. coli, Y. enterocolitica* and *Y. parahaemolyticus*. *Lancet* 336, 1111-1115.

García C., Hernández I. 1996. Influence of salinity on the biological and biochemical activity of calciorthird soil. Plant and Soil, 178, 255-263.

Islam M.S. Draser B.S. Bradley D.J. 1990. Long term persistence of toxigenic *Vibro cholerae* 01 on mucilaginous sheet of blue-green alga, *Arabonana variabilis*. *J. Trop. Med. Hyg.* 93,133-139.

Kiziloglu F.M., Turan M., Sahin U., Angin I., Anapali O., Okuroglu M. 2007. Effects of wastewater irrigation on soil and cabbage-plant (*Brassica olerecea* var. capitate cv. yalova-1) chemical properties. Journal of Plant Nutrition and Soil Science, 170, 166-172.

Kiziloglu F.M., Turan M., Sahin U., Kuslu Y, Dursun A. 2008. Effects of untreated and treated wastewater irrigation on some chemical properties of cauliflower (*Brassica olerecea* L. var. botrytis) and red cabbage (*Brassica olerecea* L. var. rubra) grown on calcareous soil in Turkey. Agricultural Water Management, 95, 716-724.

Lindsay W. L., Norvell W. A. 1978. Development of a DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of America Journal* 42, 421-428.

Madrid F., Lopez R., Cabrera F. 2007. Metal accumulation in soil after application of municipal solid waste compost under intensive farming conditions. Agriculture, Ecosystems and Environment, 119, 249-256.

Manicas P., Navas A., Bermudez F., Machn J. 1998. Influence of sewage sludge application on physical and chemical properties of Gypsisols. Geoderma 87, 123-135.

McLean E. O. 1982. Soil pH and Lime Requirement. In: Page A.L. (Ed.), Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties, Second Edition. American Society of Agronomy Inc., Soil Science Society of America Inc., Madison, Wisconsin, pp. 199-223.

Mertens D. 2005a. AOAC Official Method 922.02. Plants Preparation of Laboratuary Sample. Official Methods of Analysis, 18th edn. Horwitz, W., and G.W. Latimer, (Eds). Chapter 3, pp1-2, AOAC-International Suite 500, 481. North Frederick Avenue, Gaitherburg, Maryland 20877-2417, USA.

Mertens D. 2005b. AOAC Official Method 975.03. Metal in Plants and Pet Foods. Official Methods of Analysis, 18th edn. Horwitz, W., and G.W. Latimer, (Eds). Chapter 3, pp 3-4, AOAC-International Suite 500, 481. North Frederick Avenue, Gaitherburg, Maryland 20877-2417, USA.

Mohammad M.J. 1986. The effect of S and H_2SO_4 application on the availability of Fe, Mn, and Zn in calcareous soils. MS Thesis, Washington State University, Pullman, WA.

Mohammad M.J., Mazahreh N. 2003. Changes in soil fertility parameter in response to irrigation of forage crops with secondary treated wastewater. Communication in Soil Science and Plant Analysis, 34, 1281-1294.

Nelson D. W., Sommers L. E. 1982. Total Carbon, Organic Carbon and Organic Matter. In: Page A.L. (Ed.), Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties, Second Edition. American Society of Agronomy Inc., Soil Science Society of America Inc., Madison, Wisconsin, pp. 539-577.

Olsen S.R., Cole C.V., Watanabe F.S., Dean L.A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circular 939:1-19, Washington, DC.

Pomares F., Roca J., Tarazona F., Estale M. 1984. Aerobically digested sewage sludge as N and P fertilizer. In: Hermite, P.L., Ott, H. (Eds.), Processing and use of Sewage Sludge. Proceedings of the Third International Symposium Held a Brighton, 27-30 September 1983, D.Reidel Publishing Co., Dordrecht, Holland, 313-315.

Rhoades J.D. 1996. Salinity: Electrical conductivity and total dissolved solids. In: Sparks, D.L. (Ed.), Methods of Soil Analysis, Part 3, Chemical Methods. Soil Science Society of America, Madison, Wisconsin, pp. 417–435.

SAS 1982. SAS Users Guide. SAS Institute, Cary, N.C.

Siebe C. 1998. Nutrient inputs to soils and their uptake by alfalfa through long-term irrigation with untreated sewage effluent in Mexico. Soil Use and Management, 13, 1-5.

Soil Survey Staff, 1992. Keys to Soil Taxonomi. 5th Edition. SMSS Technical monograph No:19, Pocahontas Pres. Inc., Blacksburg.

Sommers L.E. 1977. Chemical composition of sewage sludges and analysis of their potential use as fertilizers. J. Environ. Qual., 6, 225 -232.

Soumare M., Tack F.M.G., Verloo M.G. 2003. Effects of a municipal solid waste compost and mineral fertilization on plant growth in two tropical agricultural soils of Mali. Bioresource Technology, 86, 15-20.

Sumner M.E., Miller W.P. 1996. Cation Exchange Capacity and Exchange Coefficients. In: Sparks, D.L. (Ed.), Methods of Soil Analysis, Part 3, Chemical Methods. Soil Science Society of America, Madison, Wisconsin, pp. 1201-1230.

Vazquez Montiel, O. Horan N.J., Mara D.D. 1996. Management of domestic waste-water for reuse in irrigation. Water Sci. Technol., 33, 355-362.

WHO, 2004. Guidelines for Drinking-Water Quality. Third Edition, Volume 1: Recommendations. World Health Organization, Geneva.

Woomer P.L., Martin A., Albrecht A., Reseck D.V.S., Scharpenseel H.W. 1994. The Importance and Management of Soil Organic Matter in the Tropics. In Woomer, P.L., Swift, M.J. (Eds.), The Biological Management of Tropical Soil Fertility. John Wiley & Sons, Chichester, UK, pp. 47-80.