HUNGARIAN AGRICULTURAL ENGINEERING
N° 29/2016 44-50
Published online: http://hae-journals.org/
HU ISSN 0864-7410 (Print) / HU ISSN 2415-9751(Online)
DOI: 10.17676/HAE.2016.29.44

PERIODICAL OF THE COMITTEE OF AGRICULTURAL AND BIOSYSTEM ENGINEERING OF
THE HUNGARIAN ACADEMY OF SCIENCES
and
SZENT ISTVÁN UNIVERSITY
Faculty of Mechanical Engineering

EFFECTS OF IRRIGATION WITH TREATED DOMESTIC WASTEWATER ON VARIOUS CHEMICAL PROPERTIES OF THE SOIL

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Abstract

The present study aimed to investigate the impacts of irrigation using treated wastewater on various soil chemical properties. The research was conducted over three years by completely randomized design with three replications. Treated domestic wastewater, well water and mixtures of these waters were used in the experiment. Five different irrigation treatments were designed. According to the results of analysis, Na, K, Ca, Mg, Cl and SO4 in soil extracts increased very slightly, while HCO3 decreased slightly.

Keywords

domestic waste water, irrigation, water properties, soil extract properties

1. Introduction

Turkey is a country whose water resources are at risk from global warming. For this reason it is of the utmost importance that the country should use its water resources in an efficient way.

Turkey's average annual rainfall is 643 mm, which is equivalent to an annual average of 501 billion m^3. A large proportion of this water is lost to evaporation, evapotranspiration, or river flow, while an annual average of 7 billion m3 comes from neighboring countries [1].

Turkey produces 3.7 km^3/year of urban wastewater and 3.0 km3/year of industrial wastewater. However, these values do not show the full extent of Turkey's wastewater, and the small size of these values is somewhat influenced by a lack of data. Until today, not all urban waste water is fully treated and so cannot be released to the environment.

When wastewater has been used in irrigation, generally beneficial results have been obtained, such as solving the problem of water scarcity, disposing of large amounts of poor quality water with minimal environmental risk, providing an economic benefit with a content of plant nutrients, and enabling the clean water currently used in agriculture to be used elsewhere [2].

Along with global warming, the average annual precipitation in the research area in recent years, 537 mm, has been progressively declining, and in 2007 fell to 219 mm. Therefore, the use of wastewater in irrigation is increasing. The content and quality of wastewater are variable, and uncertainty concerning the effects of using this water on the soil and on plants is a concern. Wastewater is sometimes used directly for irrigation, and is sometimes first subjected to varying levels of treatment.

The present study aimed to investigate the impacts of irrigation using treated wastewater on various chemical properties of soil.

2. Material and method

The research was conducted in the Menemen Plain in the west of Turkey, on loamy and silt loam textured soils. The wastewater used in the study was taken from Menemen Biological Wastewater Treatment Plant, of which capacity is 21600 m3 per day. According to long-term climate data, the average total annual rainfall is 537 mm, evaporation is 1513 mm, and the average temperature is 17°C [3].

In the study, polyester tanks of dimensions 100 x 140 x 140 cm, open above and below, and with free drainage, were employed. These tanks were located in the soil to a depth of 120 cm so that 20 cm remained above the soil surface. In order to prevent the flow of water directly downwards from the inside of the tank, a 3 cm wide piece of PVC was added 40 cm downwards from the top of the tank on all sides. The soil inside the tanks was in an undisturbed natural state.

The research was conducted over three years by completely randomized design, with three replications. Treated domestic wastewater, well water and mixtures of these waters were used in the experiment. Five different irrigation treatments were designed. The treatments were as follows: 100% domestic treated wastewater (A), 25% well water with 75% domestic treated wastewater (B), 50% well water with 50% domestic treated wastewater (C), 75% well water with 25% domestic treated wastewater (D) and 100% well water (E).

The crops used in the study were cotton and vetch. The vetch was irrigated once in March, and the cotton four times not including pre-irrigation. 105 mm of water was given at each irrigation [4].

Before each irrigation water samples were taken, and analyses were made of COD, BOD, NO3-N, total N, total P, TSS, EC, pH, B and soluble ions. Also, counts of total and fecal coliform bacteria in irrigation water were made for water from treatment works and for well water.

Soil samples were taken twice a year after the vetch and cotton harvests from a soil profile at a depth of 0-120 cm from layers whose profiles had been defined. These samples were analyzed (in me/l) for Na, K, Ca, Mg, Cl, HCO_3 and SO_4 ions in soil extract.

The evaluation of the results obtained was achieved with the help of the guidelines of FAO 29 [5], FAO 47 [6], the USEPA guide [7] on the reuse of water, the WHO guide [8] on the microbiological quality of wastewater reused in agriculture, and from Turkey, AATTUT "Technical Procedure Notice on Wastewater Treatment Facilities" (Official Gazette, dated 20.03.2010 and numbered 27527).

Graphs and tables were used in the evaluation of the physical and chemical characteristics of irrigation water quality and soil extract characteristics.

3. Results and discussion

Characteristics of Irrigation Water

Analyses were made before each irrigation of the treated wastewater used in the study, the well water used as a control, and the various mixtures of these, and the three-year averages of the results are shown in Table 1.

Table 1. Three-year averages of various chemical characteristics of the irrigation waters

Irrigation water quality parameters	Treatments				
	A	B	C	D	E
pH	7.8	7.7	7.8	7.8	7.7
EC (dS/m)	1.69	1.42	1.22	0.95	0.61
SAR	6.4	5.3	4.5	3.6	1.9
Bor (mg/l)	0.68	0.59	0.49	0.42	0.26
Na (me/l)	9.3	7.2	5.8	4.1	1.9
K (me/l)	0.5	0.4	0.3	0.3	0.2
Ca (me/l)	4.4	3.9	3.5	3.0	2.1
Mg (me/l)	5.4	4.4	4.0	3.0	2.1
HCO_3 (me/l)	8.6	7.4	6.9	6.0	4.5
Cl (me/l)	8.4	6.6	5.3	3.6	1.6
SO_4 (me/l)	2.6	1.9	1.4	0.8	0.4
COD (mg/l)	49	40	33	29	22
BOD (mg/l)	27	22	18	16	12
Total Suspended Solids (mg/l)	10	7	5	4	3
NO_3-N (mg/l)	14	11	10	7	5
Total P (mg/l)	2.6	2.0	1.5	0.9	0.2
Total N (mg/l)	38	30	23	21	15
Total coliform (CFU/100ml)	$2.4*10^5$	-	-	-	$8.6*10^2$
Fecal coliform (CFU/100ml)	$5.9*10^3$	-	-	-	$4.4*10^1$

The pH values of the waters used in the study did not differ greatly between experimental treatments. In terms of three-year general average values, these waters were within the limits set by AATTUT and FAO 47, and caused no problems.

When the irrigation treatments were evaluated according to AATTUT and FAO 47, it was concluded that well water (0.61 dS/m) would not cause a problem with regard to electrical conductivity, but that the other waters (0.95-1.69 dS/m) would cause problems at a medium level. With regard to boron, no restriction was found for use in irrigation for any of the treatments. Treatment E, with 1.9 me/l of Na, could be used without problems in surface and sprinkler irrigation, but treatment A, with 9.3 me/l of Na, could cause serious problems when used in surface irrigation. The other treatments, with Na contents varying between 4.1 and 7.2 me/l, could cause medium problems when used for surface or sprinkler irrigation. In terms of HCO_3 content, treatment A, with 8.6 me/l of HCO_3, could cause serious problems when used for irrigation, while the other treatments could cause medium problems. With regard to Cl content, treatment E could be used without problems in surface and sprinkler irrigation, as could treatment D in surface irrigation, while the other treatments could be used in surface and sprinkler irrigation with medium-level problems. In terms of NO_3-N content, treatment E, with 5 mg/l of NO_3-N, was in class I which would not cause problems, but treatment A, with 14 mg/l of NO3-N, was in class III which could cause medium problems.

It was found that although the amount of Mg in treatment A could cause serious problems when used in irrigation according to FAO 29, there would be no problems in the other treatments.

Examining BOD5 values in the pollution parameters according to AATTUT and USEPA (the US Environmental Protection Agency), it was found that treated wastewater could only be used in crops which were to be processed and in the surface irrigation of orchards and vines. In treatment A, the COD value was 49 mg/l and the TSS value was 10 mg/l; in treatment E these values were 22 mg/l and 3 mg/l respectively; thus both treatments were in class I.

According to AATTUT and USEPA, treated wastewater cannot be used because of the fecal coliform count, and well water can only be used in crops which are to be processed and in the irrigation of trees and vines. According to the WHO (WHO, 1989), well water can be used in the irrigation of grains and fields or plantations of industrial crops, but is not to be used in the irrigation of crops which are consumed raw, parks which are open to the public, or sports fields.

The amount of soluble cations and anions in the soil extract

At the beginning of the experiment, after the harvest of each crop and at the end of the experiment, soil samples were taken from layers on which pedon description had been performed. The content (me/l) of Na, K, Ca, Mg, HCO_3, Cl, and SO4 of the extract of these soils samples was determined, and graphs were drawn of the temporal variations in the soil layers.

Figure 1 shows the temporal variation in Na contents by soil layer. An increasing trend was seen in Na values throughout the experiment in all irrigation treatments and all soil layers. The increase was greatest in treatment A, and varied according to the proportion of treated waste water in the irrigation water of the treatments. However, this increase was not continuous, and while there was an increase in the 0-28, 28-43, 43-67 and 0-120 cm soil layers in samples taken at the cotton harvest, there was a decrease in samples taken in those layers after the harvest of vetch, grown as a winter crop. In the 67-86 and 86-120 cm layers, increases after the cotton harvest and decreases in samples taken after the vetch harvest were irregular.

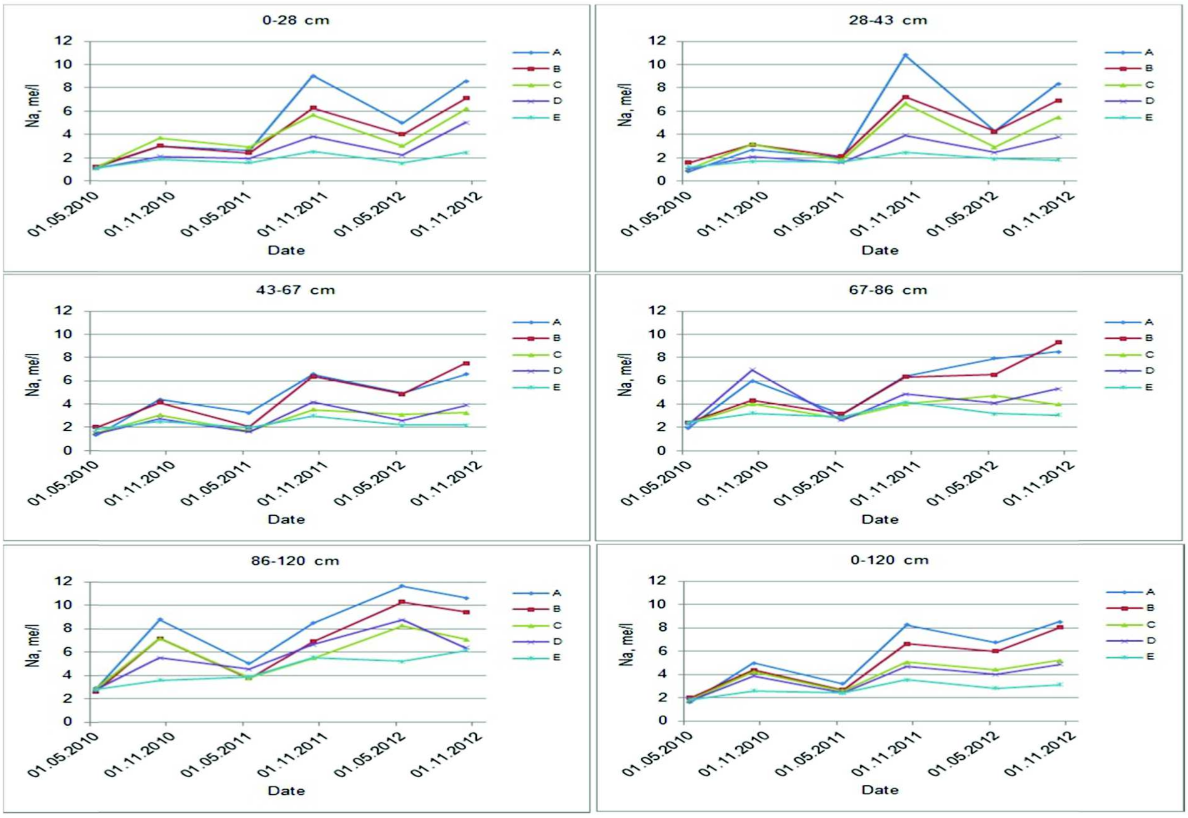

Figure 1. Temporal variation in the Na value of experimental soil extract by research treatments and soil layers

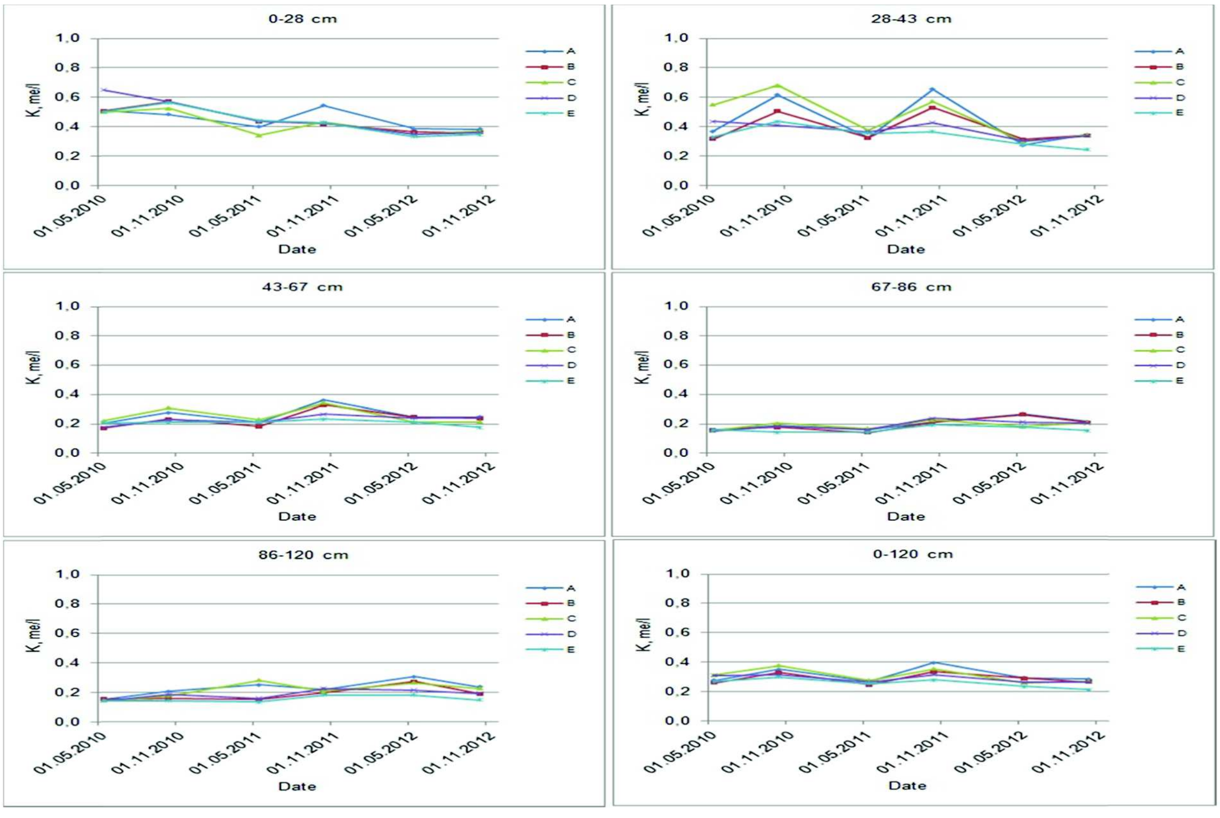

Figure 2. Temporal variation in the K value of experimental soil extract by research treatments and soil layers

Figure 2 shows the temporal variations in content of the element potassium (K, me/l) in the soil extract from the experimental soils by soil layers. An examination of the figure shows that in the 0-28 and 28-43 cm soil layers there was a decreasing trend from 0.5 me/l to 0.35 me/l over the course of the experiment in all irrigation treatments. However this decrease was not continuous in the 28-43 cm soil layer, and there was an increase in the samples taken at the cotton harvest, and a decrease in the samples taken after the harvest of vetch grown as a winter crop. In other soil layers, levels remained unchanged at 0.2 me/l throughout the experiment.

Figure 3 shows the temporal variation of the element calcium (Ca, me/l) in the soil extract from the experimental soils by soil layer. An examination of the figure shows that there was no great variation in calcium values throughout the experiment in the 0-28 cm soil layer of all the treatments. In the 28-43 cm and 43-67 cm layers however there was an increase in samples taken at the cotton harvest and a reduction in samples taken after the harvest of vetch, which was grown as a winter crop. In the 28-43 cm and 43-67 cm soil layers, the amount of calcium, which was approximately 2 me/l at the beginning of the experiment, varied at the end of the experiment from 1.5 to 4.0 me/l according to the proportions of wastewater used in the irrigation treatments. In the 86-120 cm soil layer, the amount of calcium was approximately 1.0 me/l, and at the end of the experiment it varied between 1.0 and 3.0 me/l according to the proportion of wastewater used in the irrigation treatments.

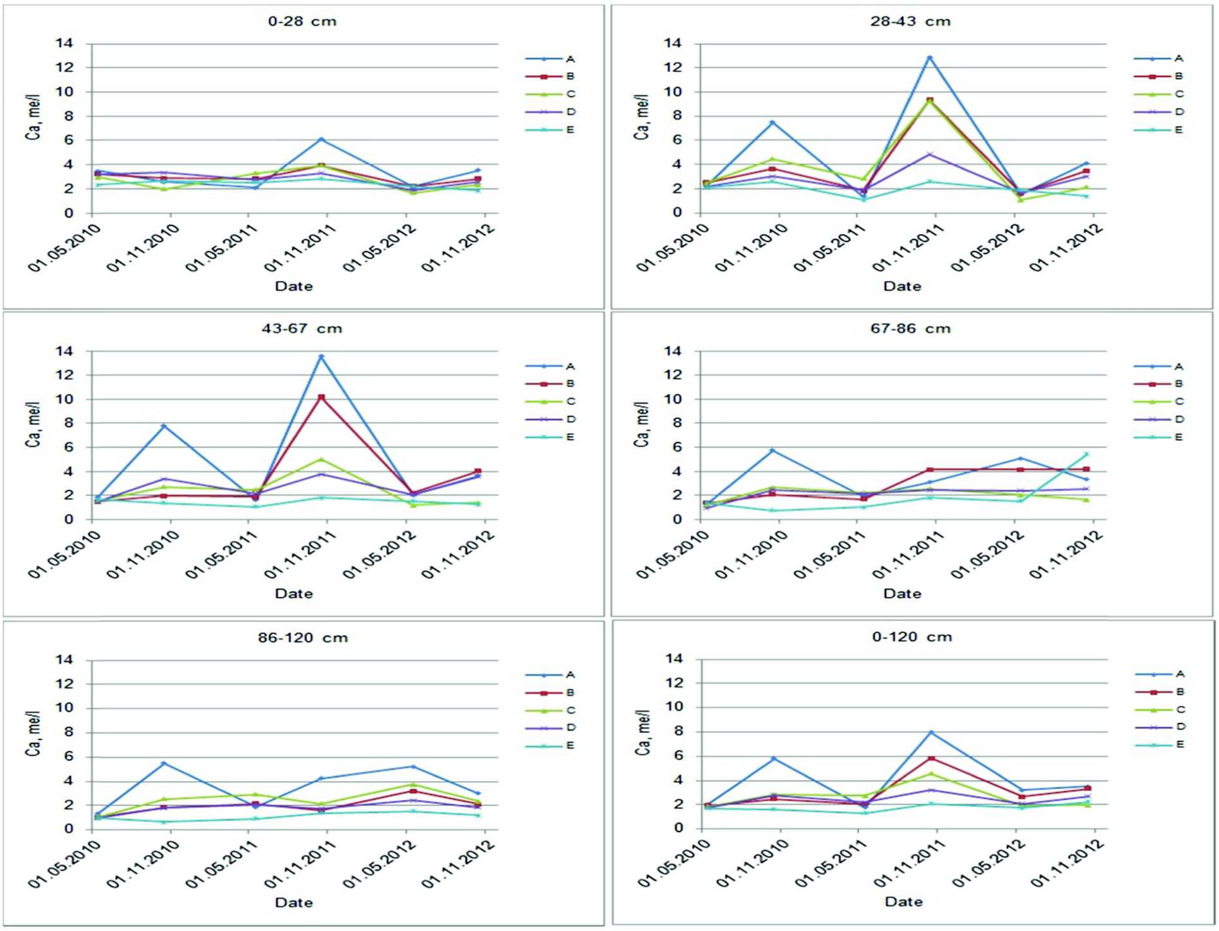

Figure 3. Temporal variation in the Ca value of experimental soil extract by research treatments and soil layers

Figure 4 shows the temporal variation in magnesium content (Mg, me/l) in the soil extract from the experimental soils by soil layers. An examination of the figure shows an increasing trend in magnesium values throughout the experiment in all soil layers of all irrigation treatments. Increases in magnesium were greatest in treatment A, and varied in relation to the proportion of wastewater used in the irrigation treatments. However, this increase was not constant, and while there was an increase in the 0-28, 28-43, 43-67 and 0-120 cm soil layers in samples taken at the cotton harvest, there was a decrease in samples taken after the harvest of vetch grown as a winter crop. In samples taken after the vetch harvest in 2012, there was an increase in Mg values in the 67-86 cm and 86-120 cm soil layers, in contrast to a decrease in the other soil layers.

Figure 5 shows the temporal variation in the HCO_3 content (me/l) of the soil extract from the experimental soils by soil layers. In all soil layers and all irrigation treatments a decreasing trend in HCO_3 values was observed throughout the experiment. This decrease averaged 5.1-3.4 me/l in the 0-28 cm soil layer, 4.3-2.5 me/l in the 28-43 cm layer, and 3.6-2.3 me/l in the 43-67 and 67-86 cm layers.

Figure 6 shows the temporal variation in chlorine content (Cl, me/l) in the soil extract from the experimental soils by soil layers. An examination of the figure shows an increasing trend in chlorine values throughout the experiment in all irrigation treatments and all soil layers. Increases in chlorine were greatest in treatment A, and varied in relation to the proportion of wastewater used in the irrigation treatments. However, this increase was not constant, and while there was an increase in the 0-28, 28-43, 43-67 and 0-120 cm soil layers in samples taken at the cotton harvest, there was a decrease in samples taken after the harvest of vetch grown as a winter crop. In samples taken after

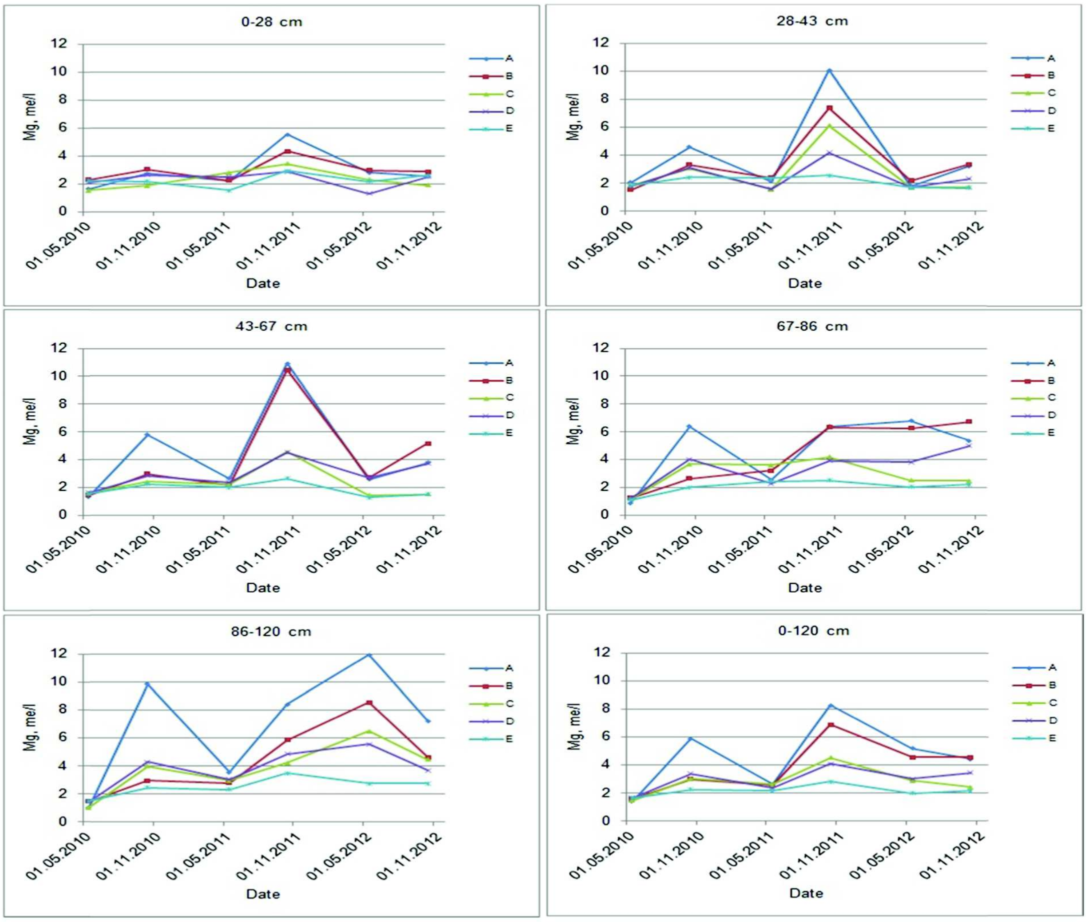

Figure 4. Temporal variation in the Mg value of experimental soil extract by research treatments and soil layers

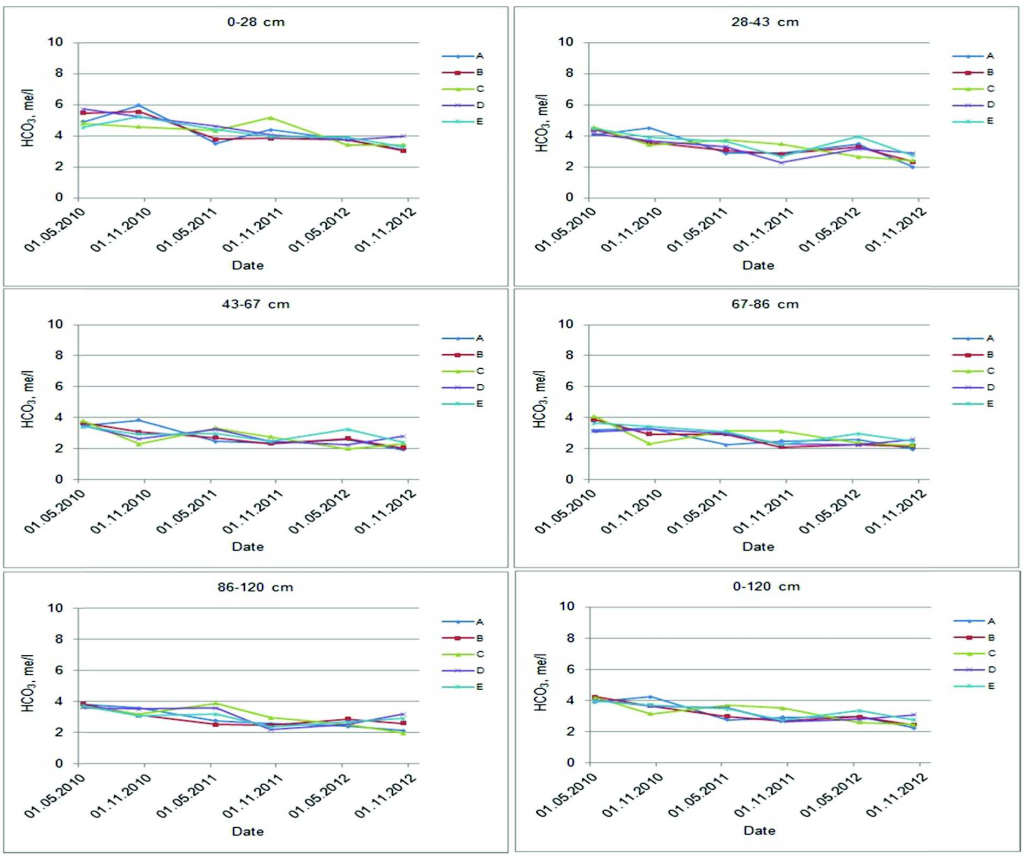

Figure 5. Temporal variation in the HCO3 value of experimental soil extract by research treatments and soil layers

the vetch harvest in 2012, there was an increase in Cl values in the 67-86 cm and 86-120 cm soil layers, in contrast to a decrease in the other soil layers.

Figure 7 shows temporal variations in SO_4 content in the soil extract from the experimental soils by soil layer. An examination of the figure shows that SO_4 values showed an increasing tendency throughout the experiment in all irrigation treatments and all soil layers. This increase in SO_4 values was greatest in treatment A, and varied according to the proportion of wastewater used in irrigation. However, the increase varied irregularly by soil layers.

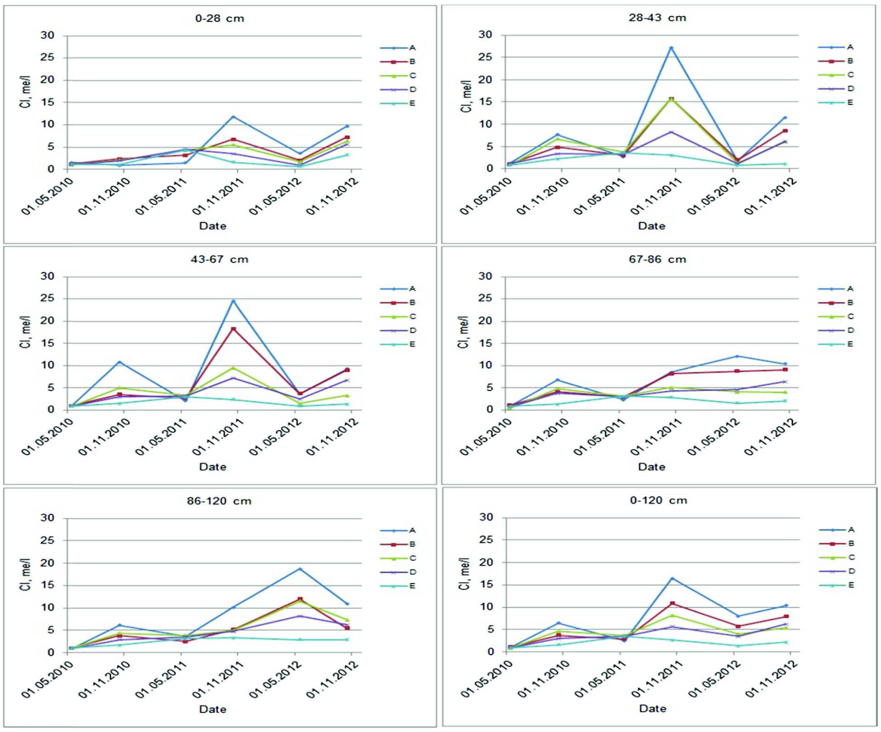

Figure 6. Temporal variation in the Cl value of experimental soil extract by research treatments and soil layers

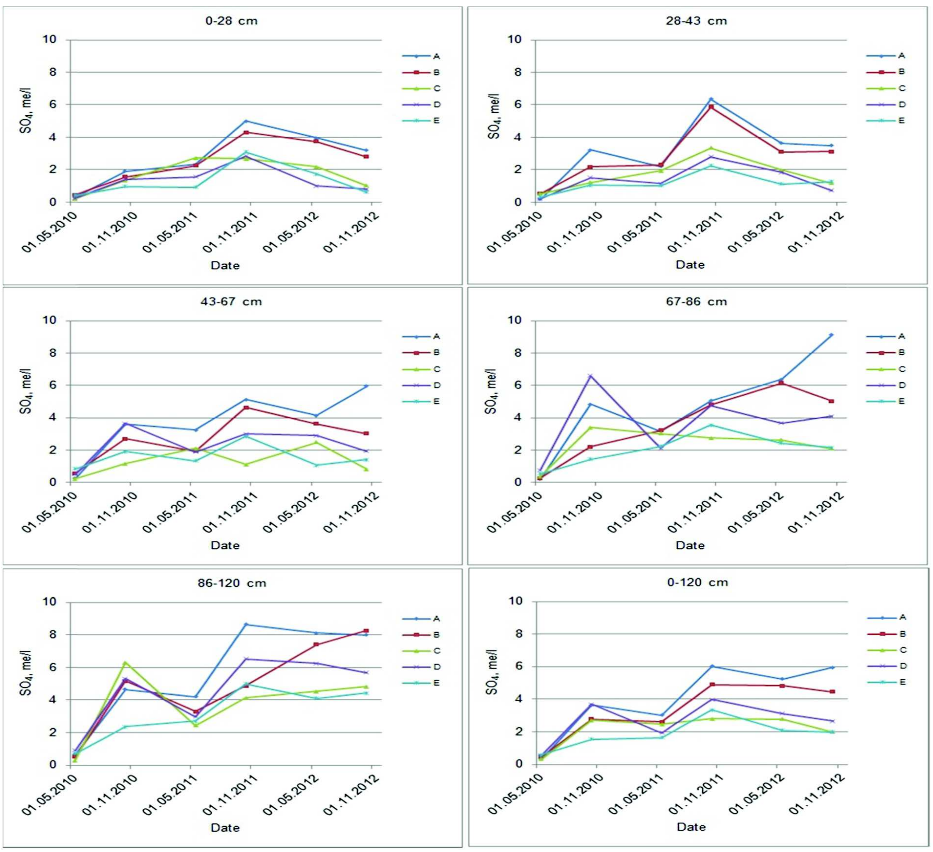

Figure 7. Temporal variation in the SO_4 value of experimental soil extract by research treatments and soil layers

4. Conclusion

This study was conducted with the aim of determining the effect of treated urban wastewater on various chemical characteristics of the soil. In accordance with this aim, extracts were prepared from soil samples and these were analyzed. The results showed that Na, Mg, Cl and SO4 values generally showed an increase compared with the beginning of the experiment in all treatments and in all soil layers, while HCO3 values showed a decrease. K values fell compared with the beginning of the experiment in the first two layers of all irrigation treatments, but generally did not change in the other layers. Ca values generally showed no change compared with the beginning of the experiment in the first layer of all irrigation treatments, but in other layers increased slightly.

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