

# Evaluation of Chemical Elements of Soil Irrigated with Industrial and Urban Wastewater

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## ABSTRACT

In Iran, water scarcity is one of the major constraints on agricultural activities. The reuse of industrial and urban wastewater in agriculture can be a sustainable solution to water scarcity. This study is a comparative research work to evaluate the effect of irrigation with industrial (a sugar factory) and urban wastewater on soil chemical elements. It was carried out in a randomized complete block design with five treatments (well water, T1; treated urban wastewater, T2; 33% water + 66% treated wastewater, T3; industrial wastewater, T4; and combined water and wastewater at 1:7 ratio; T5) in three replication. The samples were taken from the soil depth of 0-40 cm in the agricultural land of Bori-Abad in Torbat-Heydarieh, Iran. The studied parameters included nitrogen, potassium and phosphorus contents, acidity, and salinity. The results revealed an increase in N, acidity, and K in soils irrigated with urban wastewater compared to that irrigated with industrial wastewater. However, soil P and salinity were lower in urban wastewater-irrigated soil. It can be concluded that wastewater can increase some elements of soil, contributing to its restoration.

## 1. Introduction

Iran has an arid and semi-arid climate. The highest share of water consumption is accounted for by the agricultural sector. The critical status of water scarcity in many parts of Iran has made water resource planners and managers consider conventional and unconventional water resources in development planning (Shojaei et al. 2017).

Urban and industrial wastewater provides a reliable source of water and nutrients for crops (Jimenez-Cisneros, 1995) with a consequent partial reduction in the use of chemical fertilizers and improvements in crop yields (Shende, 1985; Chaabouni et al., 1997; Coppola et al., 2005). However, the application of urban and industrial wastewater can pose several risks to either agriculture crops (Yadav et al., 2002) or physical and chemical properties of the soils (Tarchouna et al., 2010) because of heavy metals and other components. The changes in the physical and chemical properties of soil induced by the irrigation with urban and industrial wastewater can affect water mobility in soils and alter soil hydraulic properties.

Therefore, it is necessary to examine the long-term effects of irrigation with wastewater on the soils. The application of wastewater in agriculture can help maintain soil fertility through relative improvements in the physical, chemical, and biological properties of the soil (Nadi et al., 2010).

Several studies have been done to investigate the effects of irrigation with industrial and urban wastewater in different regions of the world on physical and chemical properties of soils. For instance, Li et al. (2006) reported that organic matter, microorganisms, fiber, and sediments of sewage deposited in the soil surface exerted a negative impact on soil physical traits, resulting in the loss of soil permeability and soil compaction.

Heidarpour et al. (2007) investigated the effects of wastewater on soil chemical properties using two irrigation methods (subsurface irrigation with porous pipe, and surface irrigation) in Mahmoudabad Research Centre of Isfahan, central Iran in 2005 and concluded that the amount of K in the first and second layers of the soil irrigated with wastewater was significantly higher than that of the soil irrigated with groundwater.

Salehi et al. (2008) evaluated the effect of urban sewage on the soil, showing an increased concentration of N, P, K, Ca, and Mg in the soil irrigated with urban sewage compared to the soil irrigated with well water.

Rezapour et al. (2012) examined the impact of long-term wastewater irrigation on the variability of soil attributes along with a landscape in the semi-arid region of Iran. The results showed that irrigation with wastewater reduced the bulk density of the surface layer and increased its specific mass.

Karimzadeh (2012) investigated the effect of irrigation with wastewater on the saturated hydraulic conductivity of the soil. The results showed that the farms with wastewater

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with total suspended solids of 60 mg L<sup>-1</sup> floating in water limits ks in different textures.

Imam Qoli (2012) evaluated the effect of urban sewage on chemical properties of soil, showing that wastewater-irrigated sample had lower electrical conductivity, dissolved sodium content, total soluble Ca, Mg, and K, as well as higher N and P than control.

Bedbabis et al. (2014) investigated the effect of irrigation with treated wastewater (TWW) on soil chemical properties and infiltration rate. Soil samples were collected from each treatment at the beginning of the study and after four years. They recorded electrical conductivity (EC), pH, soluble cations, chloride (Cl), sodium adsorption ratio (SAR), organic matter (OM) and infiltration rate of the soil. The results of this 4-year study showed that the effect of the irrigation with TWW was significant on some physical and chemical properties of the soil.

Schacht and Marschner (2015) assessed the effect of TWW on soil hydraulic conductivity and aggregate stability of loamy soils in Israel. Their results showed that irrigation with TWW reduced soil hydraulic conductivity and soil aggregate stability.

Khodadadi et al. (2015) investigated the effects of wastewater including municipal and industrial wastewater and river water on some soil physical characteristics in agricultural lands of Lenjan Zarrin Shahr County. The results showed that the irrigation with wastewater had a negative effect on physical properties and changed particle size distribution. They recommended that the effect of long-term use of wastewater on soil physical properties should be monitored.

Silva et al. (2016) investigated the effects of irrigation with TWW and N fertilization on the chemical characteristics of a Haplustalf soil cultivated with cotton and reported that TWW provides greater accumulation of micronutrients, K and Na in the soil, increasing the risk of sodification in the irrigated areas.

Gharaibeh et al. (2016) evaluated the effect of irrigation with TWW on soil physico-chemical and hydraulic properties. The results of this study suggested that TWW could be used as an alternative source of irrigation water. However, care should be given to the high level of dissolved and suspended solids, high organic material content, and high Na percentages. Wei et al. (2017) studied the effects of reclaimed water irrigation and N fertilization on the chemical properties and microbial community of soil and concluded that the reclaimed water irrigation increased soil electrical conductivity (EC) and soil water content (SWC).

Nader et al. (2017) focused on the physical and chemical properties of soils and their earthworm community characteristics in different areas irrigated with wastewaters and well waters. The results showed that the maximum water retention capacity could be better explained by the fine texture of the soil at the effluent border.

Irandoost and Salehi Tabriz (2017) assessed the effects of wastewater and refined wastewater of Shiraz on soil chemical properties. All samples from the middle of 15 plots at the depths of 0-30 and 30-60 cm were tested in a randomized complete block design with three replications. The results showed a decrease in acidity, salinity, P, N, and heavy metals concentration in soils irrigated with wastewater versus the soils irrigated with well water. Biswas et al. (2017) studied physicochemical properties of soil under wheat cultivation by irrigation with municipal wastewater in Bangladesh. They showed that exchangeable cations-sodium (Na), potassium (K), calcium (Ca) and magnesium (Mg) were increased significantly with wastewater application.

Shojaei et al. (2017) evaluated the application of wastewater at different soil depths in Zabol in an experiment on a randomized complete block design with three replications. Soil samples were collected from the studied regions at two depths of 0-30 cm and 30-60 cm and their sodium, total calcium, magnesium, acidity, and electrical conductivity were recorded. The results showed an increase in calcium, magnesium, and pH of the effluent of Zabol wastewater treatment plant compared to the control; however, electrical conductivity and chloride exhibited a decrease in wastewater-irrigated soil.

Jaramillo and Restrepo (2017) presented a literature review with a focus on the effects, both positive and negative, of wastewater use in agriculture, emphasizing the effects on the soil environment. Li et al. (2016) studied the impacts of sewage irrigation on soil properties of farmlands in China based on the development and utilization of China's farmland sewage irrigation, putting forward suggestions to the development prospect in the near future.

Choopan et al. (2018) examined soil chemical properties affected by irrigation with untreated industrial wastewater. The results of statistical analysis showed that water stress and type of irrigation water had a significant effect on potassium, phosphorus, nitrogen, and salinity at the  $p < 0.01$  and on acidity at the  $p < 0.05$  level.

Choopan and Emami (2018) investigated soil chemical characteristic under irrigation with sugar factory wastewater and water stress and reported that irrigation with sugar factory wastewater along with water stress almost improved soil chemical properties and due to the water resources scarcity, it was recommended as an appropriate alternative for irrigation of barley fields.

The review of the literature reveals the need for studying the use of industrial and urban wastewaters in arid regions due to the scarcity of water resources. The present study aimed to assess the effect of using Torbat-Heydarieh urban wastewater and industrial (sugar factory) wastewater on the chemical elements at different depths of the soil. The main objective was to determine the effects of urban and industrial wastewater used for irrigation on soil chemical elements over two years and to figure out which of these

two irrigation types was best suited for the use and improvement of soil elements.

**2. Materials and Methods**

This research was conducted in Torbat-Heydarieh (Longitude 59°12'E and Latitude 34°17'N) region located in Khorasan-Razavi province in northeast Iran. The experimental site has an arid climate and is 1333 m above sea level. The average annual rainfall and temperature at the site are 260 mm and 21°C, respectively. The experiments included two types of water (wastewater and well water) and two crops of Barely (*Hordeum vulgare*) and cotton (*Gossypium*). The municipal wastewater used in this experiment was supplied by the wastewater treatment plant of Torbat-Heydarieh located near the city of Mashhad. The experiment was conducted in three replications. The first treatment was well water (T1) and served as control. The second treatment was municipal wastewater (T2), the third was 33% water well + 66% treated urban wastewater (T3), the fourth was industrial wastewater (T4) and the fifth was

water and industrial wastewater (with a mixing ratio of 1 to 7) (T5).

Barely was planted in May, was irrigated 10 times, and was harvested three months after planting. Cotton was planted in May, was irrigated 12 times, and was harvested four months after planting. Soil pH was determined using a pH meter (420A, Orien) in water (pH H<sub>2</sub>O), the soil salinity was assessed by determination of electrical conductivity (EC) at 25°C on a saturated paste using a conductivity meter (MC 226). Ca<sup>2+</sup> and Mg<sup>2+</sup> were measured with an atomic absorption spectrophotometer (A Analyst 200, PerkinElmer). SAR was calculated using the standard equation. The amount of water requirement was calculated using the NETWAT software. Data were statistically analyzed using the SAS 9.2 and Excel 2013 software packages.

Table 1 shows the chemical analysis of water, wastewater and water and wastewater combination.

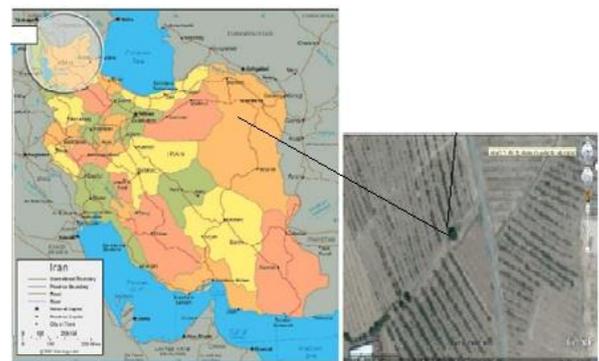
Table 2, shows the physical and chemical properties of the soil in the experimental field

**Table 1.** Chemical analysis of water, wastewater, and water and wastewater combination (with mixing ratio of 1 to 7) for the soil under the cultivation of barley and cotton

Experiment	Water and wastewater combination	Wastewater	Water	Unit	Refined wastewater
Electrical conductivity	5	20	2.5	dS/m	-
Acidity	10.7	12.1	6.8	-	-
Calcium	10	58	1.2	meq/lit	52.8
Magnesium	3.4	62	2.8	meq/lit	35.5
Sodium	25.74	65.2	18.4	meq/lit	
Carbonate	1.3	1.5	0	meq/lit	
Bi- Carbonate	3.4	8.5	3.4	meq/lit	
Chloride	30.85	57	10.5	meq/lit	608
Sulfate	7.83	120.4	10.8	meq/lit	84.9

**Table 2.** Selected soil physical and chemical properties at the experimental field

Experiment type	Unit	Experiment results
175	mg/Kg	Potassium
5.3	mg/Kg	phosphorus
0.011	%	Nitrogen
6.3	dS/m	Salinity
7.6	-	Acidity
18.75	%	Lime
0.081	%	Organic material
58	%	Gravel
9	%	Clay
33	%	Silt
27.9	%	Saturation percentage



**Figure1.** The location of the study area

**3. Results and Discussion**

Table 3 shows the results of comparison of the average salinity, acidity, phosphorus, potassium and nitrogen elements in experimental treatments that were irrigated with urban and industrial wastewater.

**Table3.** Comparison of the average chemical traits of soil in experimental treatments

Phosphorus mg/lit	Nitrogen mg/lit	Potassium mg/lit	Salinity $\mu\text{S}/\text{cm}$	Acidity (-)	Parameter Treatment
7.88a	1.23a	500a	3225c	8.92a	T <sub>1</sub>
7.85a	1.06b	486a	3239c	8.7ab	T <sub>2</sub>
8.03a	0.98c	490a	3524b	8.82a	T <sub>3</sub>

Means with the same letter(s) in each column are not significantly different at  $p < 0.05$  according to Duncan's Multiple Range Test.

**Table 4.** Comparison of the average traits of salinity, acidity, phosphorus, potassium and nitrogen elements

Acidity (-)	Salinity (dS/m)	Nitrogen (%)	Phosphorus (mg/kg)	Potassium (mg/kg)	Research Treatments
7.2d	4.2bc	0.09d	39b	209.2b	T <sub>4</sub>
7.85ab	3.9c	0.05d	19.2d	167.7c	T <sub>5</sub>

Means with the same letter(s) in each column are not significantly different at  $p < 0.05$ .

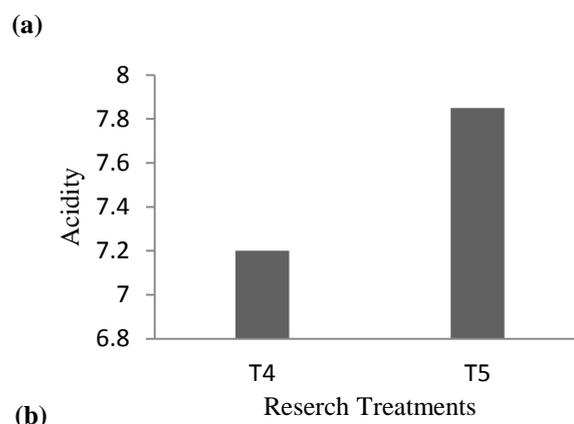
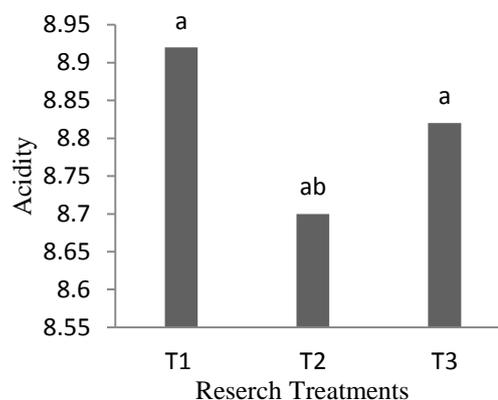
Table 4 shows the comparison of the average traits of chemical elements of soil and soil statistical analysis of the treatments for irrigation with urban and industrial wastewater.

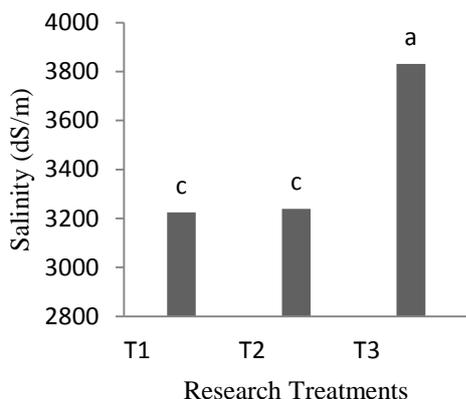
### 3.1. Acidity and Salinity

Figure 2 shows means comparison for soil acidity at 0-40cm depth. According to the results of soil chemical analysis, the acidity in the treatments was in the range of 2.7 to 8.28, which poses no problem for the cultivation of plants and soil under cultivation of crops.

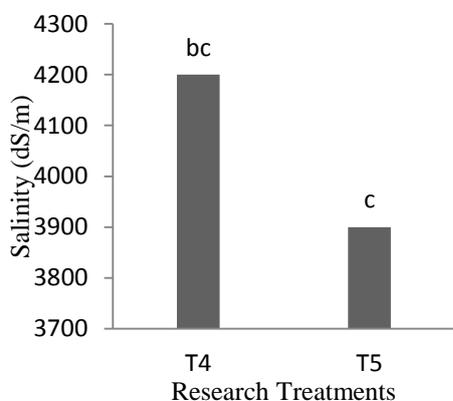
The results show that irrigation with urban wastewater decreased soil acidity (1.1%) significantly compared to irrigation with industrial wastewater, which may be due to the presence of salts and minerals in these types of resources. According to the graphs, soil acidity has increased in next depth due to irrigation with wastewater.

Figure 3 demonstrates means comparison for soil salinity at 0-40 cm depth. The results show that the soil irrigated with urban wastewater did not exhibit significantly higher salinity than the soil irrigated with industrial wastewater. The results also show that the highest salinity was observed in T4 treatment (4.2 dS/m). However, there is no significant difference among the studied depths of this treatment in terms of salinity.

**Figure2.** The amount of acidity in research treatments



(a)



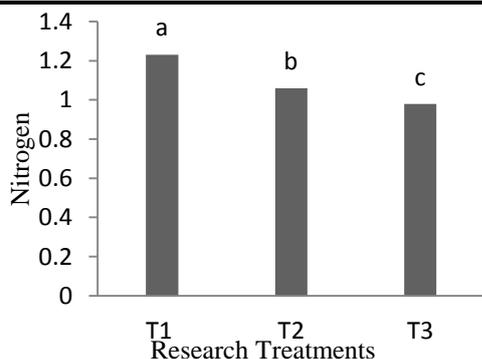
(b)

**Figure3. a and b)** The amount of salinity in research treatments

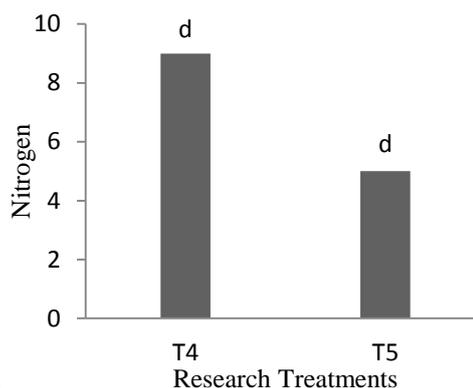
Based on the results of this study, irrigation with urban refined wastewater reduced soil salinity by up to 45% of the initial soil value before cultivation.

### 3.2. Phosphorus and Potassium

The results indicated that nitrogen, phosphorus, and potassium ions were all allowed to use the soil under research treatments for agricultural production and would not have any adverse effects on the crops. Nitrogen levels were not increased significantly in the soils treated with wastewater, water and wastewater combination. In general, it can be concluded that wastewater does not affect nitrogen content in the soil (Fig. 4).



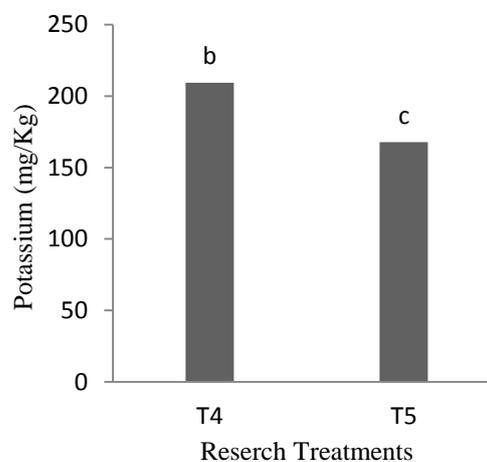
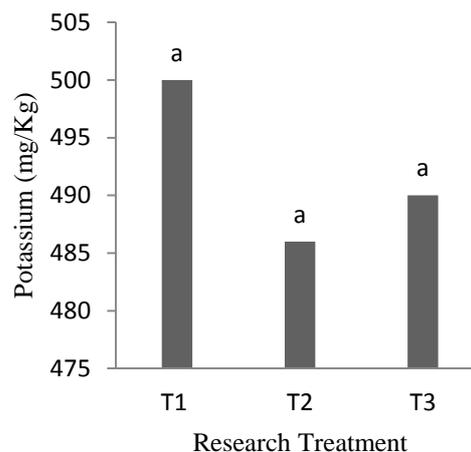
(a)



(b)

**Figure4. a and b)** The amount of nitrogen in research treatments

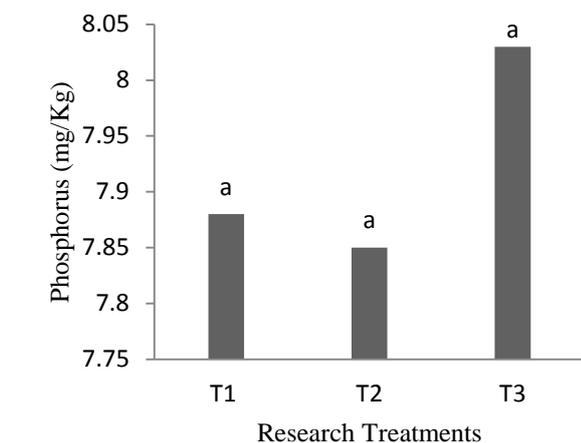
The results showed that irrigation with urban wastewater increased the amount of nitrogen in the soil compared to irrigation with industrial wastewater. This could be due to the reduced moisture and nitrogen dissolution in the soil (Agha-Barati et al., 2009; Hosinpour et al., 2009; Sharma et al., 1999).



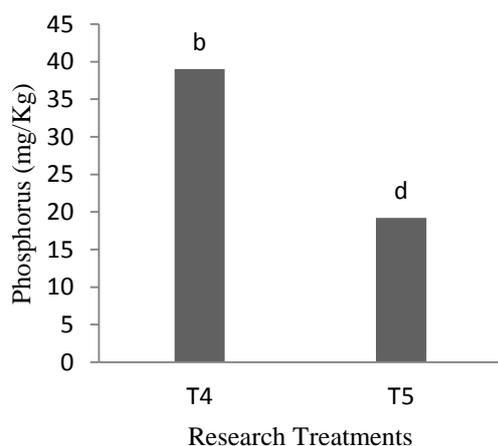
**Figure5. a and b)** The amount of potassium in research treatments

In irrigation with both industrial and urban wastewater, potassium and phosphorus had a decreasing trend due to the presence of high amounts of  $Mg^{2+}$  and  $Ca^{2+}$  in urban wastewater (Figures 5 and 6).

The accumulation of  $Mg^{2+}$  and  $Ca^{2+}$  in soils improves soil physical conditions and crop growth, but it leads to less use of potassium in chemical reactions and soil intrinsic activities.



(a)



(b)

**Figure 6. a and b)** The amount of phosphorus in research treatments

According to the results, the highest and lowest amount of potassium and phosphorus ions of 209.2 and 39 mg/kg in T<sub>4</sub> treatment was observed in irrigation with industrial wastewater, respectively. Also, Agha-Barati et al. (2009), Hosinpour et al. (2009), Sharma et al. (1999), and Jalali et al. (2008) have shown that irrigation with wastewater decreased dissolved potassium and phosphorus content of the soil as compared to control.

#### 4. Conclusions

The results of the present study showed that irrigation with wastewater decreased soil salinity dissolved chloride content of the soil, thereby decreasing chloride content by 45% at 0-40 cm depth compared to irrigation with industrial wastewater. There was also a significant difference among

all treatments at the studied depth. The results showed the lack of significant differences between the treatments at the studied depth, but all of the parameters are the standard values for irrigation of crops. The comparisons showed that irrigation with industrial wastewater of the sugar factory also increased potassium and phosphorus levels and did not change the soil salinity and acidity, but the rate of this increase was lower than irrigation with urban wastewater. In summary, irrigation with urban and industrial wastewater increased total dissolved potassium and phosphorus in the soil compared to control. These results are consistent with Shojaei et al. (2017) and Salehi et al. (2008) who showed that irrigation with wastewater increased elements concentrations in the soil as compared to irrigation with well water.

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