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Evaluating the application of wastewater in different soil depths (Case study: Zabol)

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ABSTRACT: Water scarcity, its necessity in food production, and environmental protection in the world have forced human beings to seek new water sources. Nowadays, application of unconventional water resources (wastewater) has been proposed in countries facing the crisis of water resources shortage; however, a few studies have dealt with this issue. The present study has evaluated the changes in the elements of the soil, irrigated with wastewater. For so doing, an experiment has been conducted on a randomized complete block design with three replications. Soil samples have been collected from the studied regions at two depths of 0-30 cm and 30-60 cm and the studied parameters have included sodium, total calcium, magnesium, some acidity, and electrical conductivity of the soil. Three regions of study (namely no irrigation, irrigation with treated wastewater, and irrigation with river waters) have been taken into consideration. Results have shown increased calcium, magnesium, and pH of the effluent from Zabol Wastewater Treatment Plant compared to the control; however, electrical conductivity and chloride have decreased in wastewater-irrigated soil. The electrical conductivity in the surface layer of wastewater samples, treated with an amount of 2.25 (ds/m), has had the most significant difference to the control and other treatments. It can be concluded that wastewater increases some soil properties, contributing to its restoration.

Keywords: calcium, electrical conductivity, magnesium, pH, Zabol.

INTRODUCTION

Iran has arid and semi-arid ecosystems. The highest portion of water consumption is spent on agricultural purposes, compared to others. Critical state of water scarcity in many parts of Iran has made water resource planners and managers consider conventional and unconventional water resources (low quality water resources) in development planning. Urban wastewater is a low quality water resource, the application of which in agriculture necessitates careful management. Population growth in recent decades, development of human needs, and increased public health have led to excessive exploitation of surface and underground water resources, which might result in a massive crisis. The problem is further exacerbated and highlighted in drought periods, requiring special attention in countries such as Iran that lies in an arid belt. Unconventional freshwater resources (wastewater) should be used in agriculture in order to solve the problem, so that water resources would be available for other

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purposes (Hossein Qoli, 2002). Application of unconventional water resources (such as wastewater from water-treatment plants) is increasingly important as it entails less pressure on freshwater resources (Moazed and Hanife Lu, 2006). In fact, wastewater is rich in nutrients, being the most accessible source of water for irrigation in most countries that face water scarcity (Fatta and Kythreotou, 2005). It can be used as a fertilizer, rich in nutrients.

Moreover, it seems necessary to maintain the quality and health of soil as it plays an important role in not only food production but also maintenance of environmental quality. Soil quality is defined as those ecosystem services, which increase fertility while maintaining environmental quality as well as human and animal health (Zaman et al., 2004). Nowadays, quality and health of soil and consequently the health of organisms have been seriously taken into consideration, given the extended machine life and environmental pollution (Selivanovskaya et al., 2001). Therefore, it is necessary to examine long-term effects of irrigation with wastewater on the soil. Using wastewater in agriculture can help maintain soil fertility through relative improvement in physical, chemical, and biological properties of the soil (Nadi et al., 2010). In general, unconventional water resources have different effects of the sort on the soil, which are mainly due to unfavorable physical and chemical soil qualities, with adverse effects on physical properties of the soil under plantation (e.g. soil texture, permeability, and composition) along with macro, micro, and trace elements' uptake in the soil. For instance, Salehi et al. (2008) evaluated the effect of urban sewage on the soil, showing increased concentration of nitrogen, phosphorus, potassium, calcium, and magnesium in the soil, irrigated with urban sewage, compared to the soil irrigated with well water. Abedi Koupai et al. (2001) evaluated the effect of irrigation with wastewater of Shahin Shahr Water Treatment Plant on sugar beet, maize, and sunflower. They showed that irrigation with wastewater reduces saturated electrical conductivity, increasing bulk density of the soil. Imam Qoli (2012) evaluated the effect of urban sewage on chemical properties of soil, showing that in comparison to the control, wastewater-irrigated sample has reduced electrical conductivity, dissolved sodium content, total soluble calcium, magnesium, and potassium, as well as increased nitrogen and phosphorus. The present study aims to assess the effect of using wastewater from Zahedan Water Treatment Plant on the accumulation of some elements at different depths of the soil, in order to determine changes in various elements of soil profile, and recommend appropriate management methods to apply waters with different qualities so that more adequate water resources can be identified for agricultural purposes.

MATERIALS AND METHODS

This research has lasted for 3 years, in which the effects of wastewater application on levels of sodium, total calcium, magnesium, pH, and electrical conductivity of soil have been determined. Zahedan Water Treatment Plant was selected as a case study with three sites selected for the following treatments: no irrigation, irrigation with treated wastewater, and irrigation with river water (Lar River). The area without irrigation (control) was the pasture around the Water Treatment Plant and the river water was used for flood irrigation of farmers' fields for 6 months of year. What is more, part of the land around the Water Treatment Plant was irrigated by wastewater from the plant. Some samples were collected from the studied region in order to evaluate annual changes after plantation. The samples were collected and transferred to the library. The experiment was conducted as a randomized complete block design with three replications by drilling soil profiles. Two samples were collected from each profile at two shallow depths (0-30 cm) and two deeper ones (30-60 cm). Soil samples were dried in the open air before being transferred to the laboratory. The samples were screened, using a 2 mm sieve, and transferred to the laboratory. The following steps were taken in order to determine soil acidity: soil samples were saturated with distilled water. After 24 hrs, acidity of the soil saturated extract was measured using a pH meter (Sparks et al., 1996). Once the saturated mud and saturated extract of the soil were prepared, electrical conductivity of the samples was recorded using an electrical conductivity meter device in terms of 25 $cdsm^{-1}$ (Sparks et al., 1996).

The following steps were taken in order to determine sodium level of the soil samples: a segment of saturated extract of the soil was removed and diluted until sodium concentration fell below 20 mg per liter. The wastewater standards were prepared, then, 0, 10, 20, and 50 mg of sodium levels in the distilled water were recorded, using a flame photometer. At the end, linear regression equation between sodium level as the dependent variable and recorded values as the independent one was written, using calibration curve and Microsoft Excel, as well as recorded values for the standards. Finally, sodium concentration in the diluted extract was calculated, using the equation and recorded values. Sodium concentration in the saturated sample was also measured by taking into account the degree of dilution (Sparks et al., 1996). In addition, total dissolved calcium and magnesium in the soil were measured using the complexometry method. Tables 1 and 2 give the results from the analysis of freshwater, wastewater, and soil in the studied region.

SPSS v. 11.5 was used to analyze data. Kolmogorov-Smirnov Test was used for data normality. Levene's test was used for variance homogeneity. Parametric tests were in accordance to data normality and homogeneity. Duncan's multiple range test was used for mean comparison at significance levels of 1% and 5%.

RESULTS AND DISCUSSION

Results from the analysis of freshwater and wastewater samples from Zabol Wastewater Treatment Plant show that the amount of boron (B) in the wastewater exceed the allowable agricultural range but acidity of the effluent is within the allowable range (Table 2).

ANOVA results at various depths 0-30 cm show a significant difference between chloride level and electrical conductivity of the soil at 5% significance level. ANOVA and Duncan’s test results also show no significant difference between Total calcium and magnesium content and acidity of the soil at 1% significance level. F-values are as 75.63 (Table 3).

Table 4 shows results from the analysis of variance, relevant to the effect of applied treatments at different depth. The results show that all parameters (chloride, acidity, and electrical conductivity) are significant at 5% significance level, while sodium content of the soil is significant at 1% level.

Results from the analysis of relevant variance to the effect of applied treatments at different depths for the third year indicate that levels of chloride and electrical conductivity are significant at 5% significance level, their F-values being 179.68 and 4358.29 respectively.

Table 1. Physical properties of the soil in the studied region

Clay%	Sand%	Slit%	Soil texture	Electrical conductivity (ds/m)	Acidity of saturated mud
18	14	68	Loam-silt	2.89	7.42

Table 2. Average quality of treated wastewater and freshwater

Water quality criteria	Unit	Allowed limit for agriculture	Treated wastewater 1	Water
pH	-	6.5-8.5	8	7.603
Electrical conductivity	dS/m	-	5.5	-
Sodium	SAR	-	11	3.8
Chloride	me/l	-	26.1	6
Boron	me/l	1	3.1	-
Nitrogen	me/l	-	12.2	
Calcium and magnesium	me/l	-	42	-

Extracted from the Department of Environment of Iran, 1994

Table 3. Results from the analysis of variance relevant to the effect of applied treatments at different depth 0-30 cm

Parameter	Sum of squares	Mean of squares	Statistical F	Sig.
Chloride	1.33	0. 70	44.16*	0.00
Acidity	0.67	0. 32	24.286ns	0.1
Electrical conductivity	78.10	16. 50	59.66*	0.00
Total calcium and magnesium	61120.5	20373.5	75.63**	0.00

Table 4. Results from the analysis of variance relevant to the effect of applied treatment at different depth 30-60 cm

Parameter	Sum of squares	Mean of squares	Statistical F	Sig.
Chloride	4.46	0.89	44.48*	0.00
Acidity	0.86	0.29	343.74*	0.00
Electrical conductivity	68.17	16.77	1399.19*	0.00
Total calcium and magnesium	10300. 54	3433.51	3. 19**	0.00

Table 5. Results from the analysis of variance relevant to the effect of applied treatments at different depth 60-90 cm

Parameter	Sum of squares	Mean of squares	Statistical F	Sig.
Chloride	5. 15	1.04	179.68*	0.00
Acidity	1.33	0. 68	117.14ns	0.02
Electrical conductivity	70.19	18. 32	4358.29*	0.00
Total calcium and magnesium	2830.28	943.42	4. 94**	0.00

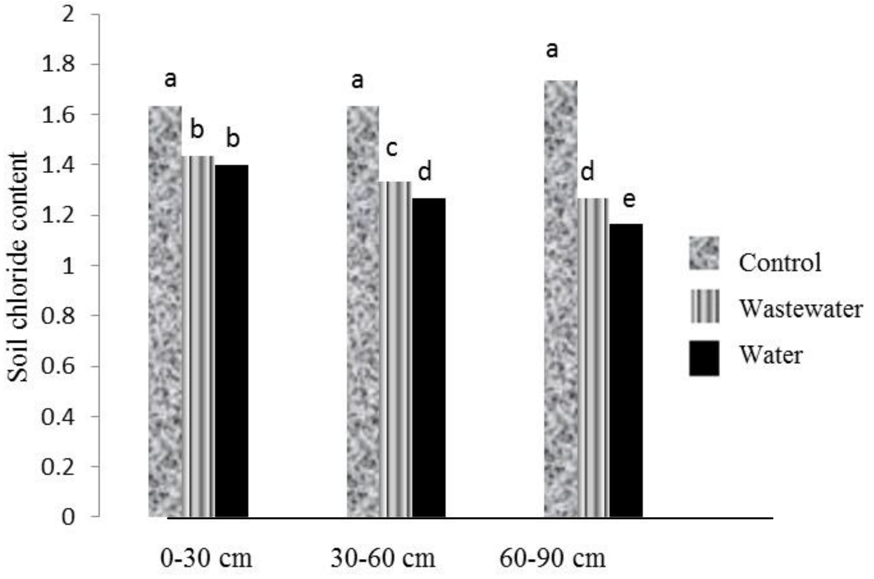

Fig. 1. Dissolved chloride content of the soil at 0-30cm depth

Figure 1 shows Duncan's test for mean comparison, relevant to the changes in soil chloride content at 0-30 cm depth. As can be observed in Figure 1, no significant difference is found between irrigation with freshwater and irrigation with wastewater in the first depth; however, in later depth there is one. Nevertheless, no significant difference can be found between control and the other two treatments at all studied periods. The least chloride content belongs to irrigation with water and irrigation with wastewater, which reduces in the soil surface as irrigation with water and wastewater continues in later depth. Chloride permeation into the soil decreases as a result of irrigation.

Figure 3 shows mean comparison of soil acidity at 0-30cm depth. The results show that irrigation with wastewater has increased soil acidity, compared to control. This difference is significant; however, irrigation with freshwater does not increase acidity. There is no difference between irrigation with freshwater and control. According to the graph, soil acidity has increased in later depth (the second and the third years) due to irrigation with wastewater. There is no difference between the 30-60 and 60-90 cm depths in wastewater irrigation in terms of soil acidity. Freshwater irrigation does not increase soil acidity significantly (Fig. 3). Increased soil acidity at 0-30 cm, 30-60 cm, and 60-90 cm depths is due to high acidity of wastewater, compared to freshwater (Table 2).

Figure 4 demonstrates mean comparison of soil electrical conductivity at 0-30 cm depth. The results show that soil electrical conductivity has declined significantly in the first depth of irrigation with wastewater and freshwater, compared to the control. In addition, there is a significant difference between irrigation with wastewater and freshwater in terms of electrical conductivity. The results also show that electrical conductivity has declined in the land, irrigated with freshwater at surface layer after the second depth. However, there is no significant difference among the studied depths of this treatment in terms of electrical conductivity.

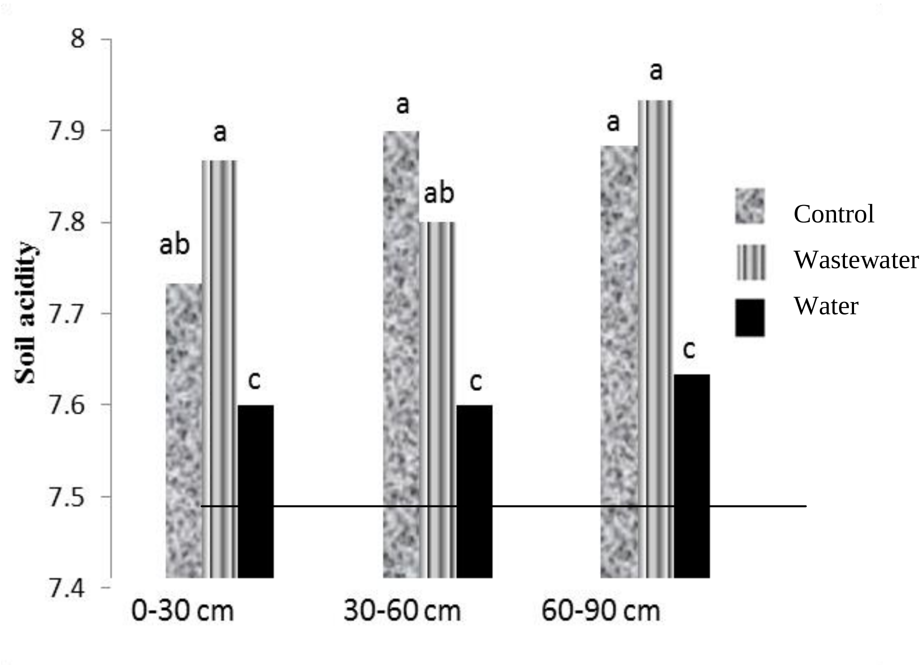

Fig. 2. Soil acidity at 30-60cm depth

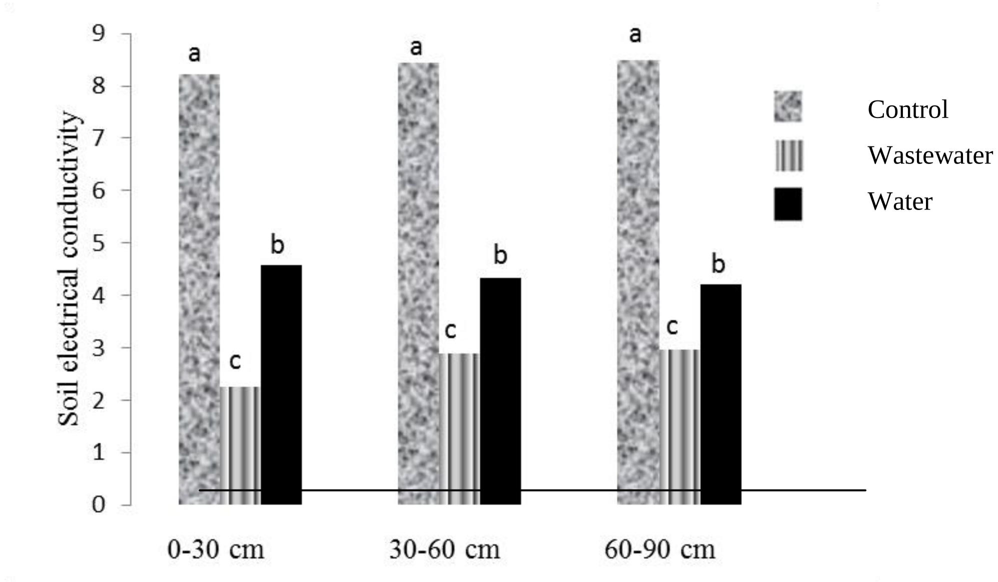

Fig. 3. Soil electrical conductivity at 0-30 cm depth

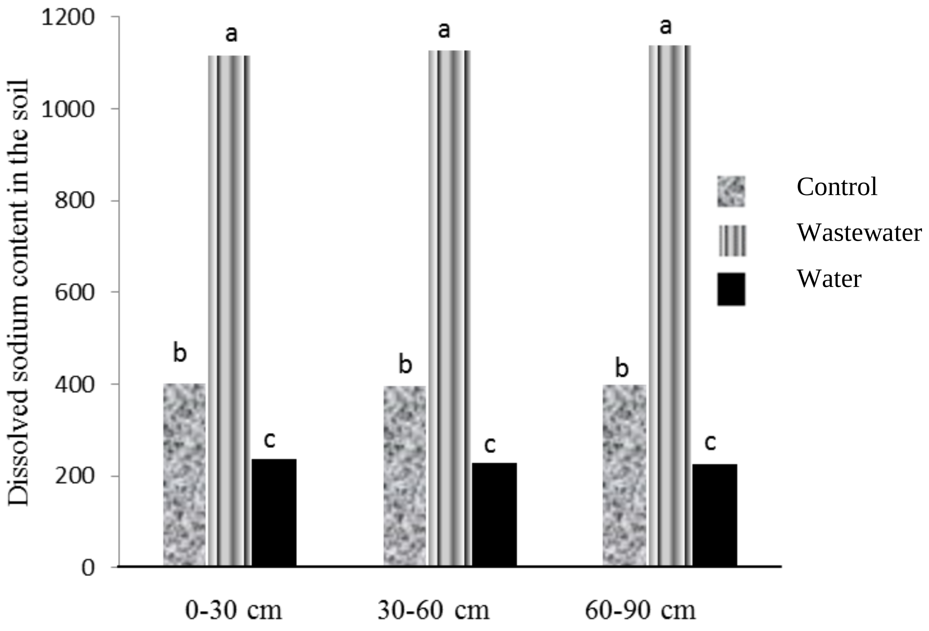

Fig. 4. Total calcium and magnesium content of the soil at 0-30cm depth

Results of mean comparison at 0-30cm depth show a significant difference among the studied areas in terms of total calcium and magnesium content of the soil (Fig. 4). In addition, in the first depth these results show that irrigation with wastewater has increased soil's total calcium and magnesium content. There is also a significant difference between all treatments in terms of total calcium and magnesium content. According to the results, irrigation with wastewater has increased total calcium and magnesium content in the second and the third depths too. There is also a significant difference between all treatments in terms of total calcium and magnesium content. Results from the analysis of wastewater show increased sodium content of the soil, irrigated with wastewater due to high total calcium and magnesium content of wastewater in comparison with freshwater (Table 2).

DISCUSSION AND CONCLUSION

Studied wastewater contained significant amounts of nutrients, needed by plants. Thereby, not only is wastewater an adequate water supply for crop irrigation but it improves soil fertility also. The most prominent chemical property of soil is its pH as many chemical properties of the soil and, consequently, plant growth, activity of soil organisms and availability of nutrients to plants depend on it (Ghollarata and Raiesi, 2007; Guidi et al., 1983). Wastewater irrigation has both positive and negative effects on soil (Osakwe, 2012). The results of ANOVA at studied depths showed no significant difference in terms of soil acidity, which can be due to the presence of organic acids and non-acidic compounds in sewage sludge (Bahremand et al., 2002). Zamani et al. (2010) studied the effect of sewage sludge of a Polydactyl factory on soil properties. They reduced soil acidity by 1.8 unit using 45 tons per hectare sewage sludge of the factory, compared to the control, observing no significant difference between the treatment and control. Results from examining electrical conductivity of soil samples in three years showed the considerable effect of irrigation with wastewater in the region at 5% significance level, hence electrical conductivity of the soil rose significantly in the areas, irrigated with wastewater, compared to control. These results are consistent with the ones, achieved by Zamani et al. (2010) who showed that saturated hydraulic conductivity was reduced by adding sewage sludge to the soil. In another experiment, north of Isfahan, the effect of irrigation with wastewater on soil properties was studied, in which the studied area was irrigated with wastewater for 9 years. Results of the former experiment showed that wastewater reduced electrical conductivity, compared to well water (Shahraki and Mahdavi, 2005).

The results of the present study showed that irrigation with wastewater decreased dissolved chloride content of the soil, hence decreasing chloride content by 12.26% at 0-30 cm depth, compared to control. There was also a significant difference among all treatments at studied depths. Hosseinpour et al. (2008) also showed that more percentage of wastewater is transported to outlet water drainage in the long run, using more wastewater; therefore, an upward trend was observed between transport percentages of soil elements over time (Hosseinpour et al., 2008). Imam Qoli (2012) evaluated the effect of wastewater on soil chemical properties, showing that irrigation with wastewater decreased dissolved chloride content of the soil, compared to control. Wastewater irrigation transported total dissolved calcium and magnesium to the soil, which increased at 30-60 cm depth. The results showed a significant difference between all treatments at the studied depths except for irrigation with freshwater and control at surface layers. In sum, irrigation with wastewater increased total dissolved calcium and magnesium in the soil compared to control. These results are consistent with the ones, obtained by Salehi et al. (2008), who showed that irrigation with wastewater increased calcium and magnesium concentrations in the soil, compared to irrigation with well water. Abegunrin et al. (2016) reported that wastewater resources are valuable, for they improve soil fertility and enhance crop growth, compared to rainwater; however, they need to be managed with care, being preferably treated before reusing, owing to soil functions and crop quality. Akbarnezhad et al. (2012) investigated impacts of urban wastewater and sewage sludge compost on chemical specifications of the soil, revealing that irrigation with urban wastewaters increase nitrogen value in treated lands. In addition, the use of domestic wastewater boost soil fertility and reduce the consumption of chemical fertilizers (Fine and Hadas, 2012). In general, usage of wastewater is an appropriate choice for irrigating agricultural products in different areas, particularly the arid and dry ones (Anderson et al., 2001).

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