Evaluation of Long-term Changes in Wastewater Application in Different Depths of Soil

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Abstract

Water scarcity and the need for water for 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 the countries facing shortage of water resources. However, limited studies have assessed this issue. The present study evaluated changes in elements of the soil irrigated with wastewater. For this purpose, an experiment was conducted as 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. Studied parameters included sodium, total calcium and magnesium, acidity and electrical conductivity of the soil. Three studied regions (no irrigation, irrigation with treated wastewater, irrigation with river waters) were considered. The results showed an increase in sodium, calcium and magnesium and pH of the effluent from Zahedan Wastewater Treatment Plant compared to control. However, electrical conductivity decreased in the soil irrigated with wastewater. It can be concluded that wastewater increases some soil properties, which contributes to soil restoration.

Key words: soil, wastewater, total calcium and magnesium, Zahedan

1. Introduction

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. This problem is exacerbated in drought periods. This crisis is more highlighted and requires special attention in such countries as Iran, which lies in the arid belt. Unconventional freshwater resources (wastewater) should be used in agriculture in order to solve this problem, so that water resources would be available for other purposes (Hussein Oghli, 2002). Abedi Koupai*et al*. (2001) evaluated the effect of wastewater of Shahin Shahr Water Treatment Plant on irrigation of sugar beet, maize and sunflower. They showed that irrigation with wastewater reduces saturated electrical conductivity and increases bulk density of the soil. Imam Qoli (1391) evaluated the effect of urban sewage on soil chemical properties. They showed that irrigation with wastewater reduces electrical conductivity, dissolved sodium content, total soluble calcium and magnesium, potassium, and increases nitrogen and phosphorus of the soil compared to control. The present study aimed to assess the effect of application of wastewater of Zahedan Water Treatment Plant on accumulation of some elements at different depths of the soil in order to determine changes in various elements of soil profile, so that more adequate water resource can be identified for agricultural purposes.

2. Materials and Methods

This research lasted for 3 years in which the effects of wastewater application on levels of sodium, total calcium and magnesium, pH and electrical conductivity of soil were determined. Zahedan Water Treatment Plant was selected as a case study. Three sites were selected where following treatments were applied to: no irrigation, irrigation with treated wastewater, irrigation with river water (Lar River). The area without irrigation (control) was the pasture around the Water Treatment Plant. The river water was used for flood irrigation of farmers' fields for 6 months every year. 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 Laboratory on 20th July every year. 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 (0-30cm) and deeper depths (30-60cm). Soil samples were dried in the open air before being transferred to the laboratory. The samples were screened using a 2mm sieve and transferred to the laboratory. Following steps were taken to determine soil acidity: soil samples were saturated with distilled water. After 24 hours, acidity of the soil saturated extract was measured using a pH meter (Sparks *et al*., 1996). After preparing saturated mud and saturated extract of the soil, electrical conductivity of the samples was recorded using an electrical conductivity meter device in terms of 25cdsm-1 (Sparks *et al*., 1996). 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 was below 20 mg per liter. The wastewater standards were prepared. Then, 0, 10, 20 and 50 mg of sodium levels in 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 variable was written using calibration curve and Microsoft Excel and 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 calculated 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. Results of analysis of freshwater, wastewater and soil in the studied region are given in Tables 1 and 2. SPSS version 11.5 was used for data analysis.

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
Calcium and magnesium	me/l	-	26.1	6
Boron	me/l	1	3.1	-
Nitrogen	me/l	-	12.2	
Calcium and magnesium	me/l	-	42	-

1- Extracted from the Department of Environment of Iran, 1994.

Table 3 –results of analysis of variance relevant to the effect of applied treatments atdifferent depths (the first year)

Parameter	Sum of squares	Mean of squares	Statistical F	Sig.
Calcium and magnesium	2.782	0.696	48.156*	0.00
Acidity	0.842	0.210	22.286ns	0.1
Electrical conductivity	68.342	17.085	66.616^	0.00
Sodium	2370867.111	592716.778	9179.086**	0.00

Table 4 – results of analysis of variance relevant to the effect of applied treatment at different depths (the second year)

Parameter	Sum of squares	Mean of squares	Statistical F	Sig.
Calcium and magnesium	3.356	0.839	44.418*	0.00
Acidity	0.875	0.219	393.14*	0.00
Electrical conductivity	67.187	16.797	1379.29*	0.00
Sodium	2473936.834	618484.208	46341.075**	0.00

Table 5 – results of analysis of variance relevant to the effect of applied treatments at different depths (the third year)

Parameter	Sum of squares	Mean of squares	Statistical F	Sig.
Calcium and magnesium	4.015	1.004	180.68*	0.00
Acidity	1.471	0.368	115.114ns	0.02
Electrical conductivity	72.129	18.032	405.279*	0.00
Sodium	2541991.092	635497.773	27697.240**	0.00

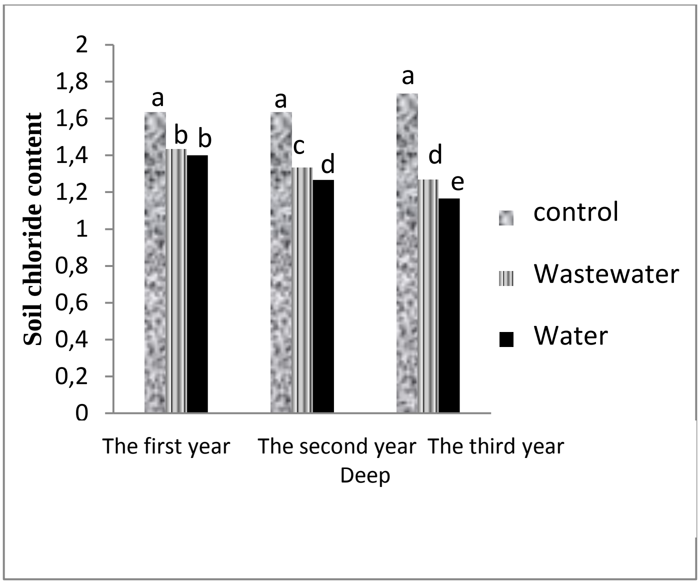

Figure 1 – dissolved calcium and magnesium content of the soil at 0-30cm depth.

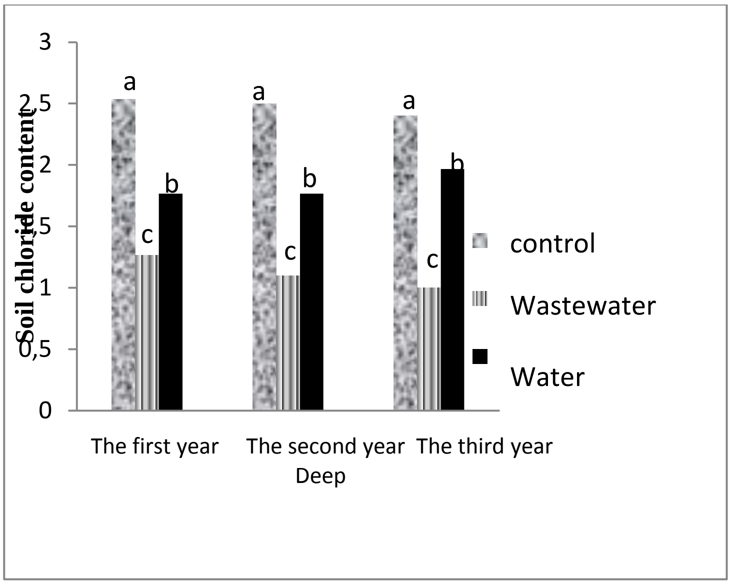

Figure 2 –dissolved calcium and magnesium content of the soil at 30-60cm depth.

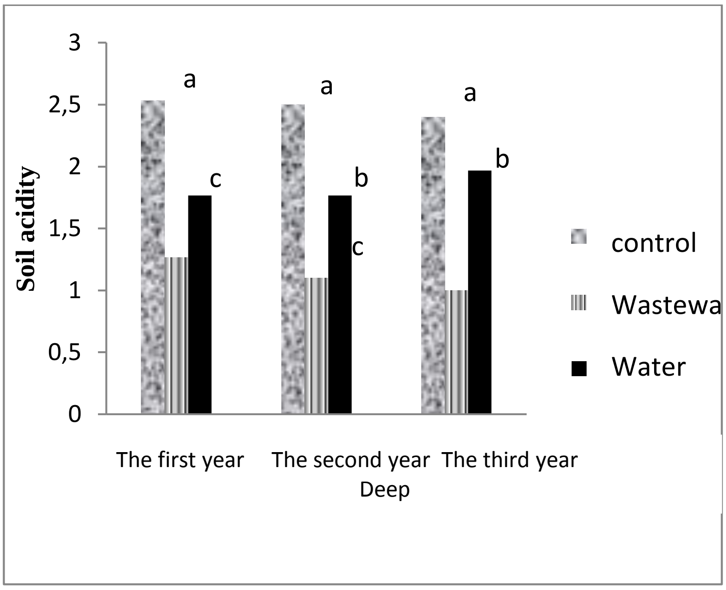

Figure 3 . soil acidity at 0 -30cm depth.

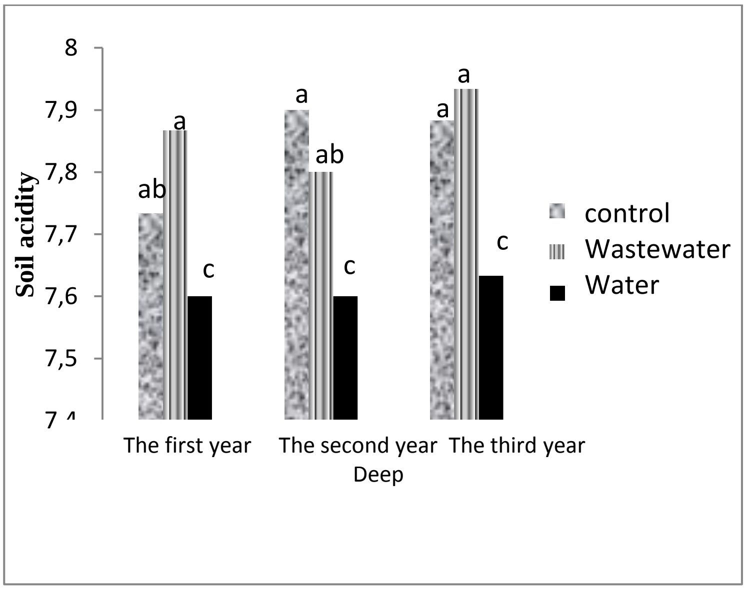

Figure 4 . soil acidity at 30-60cm depth.

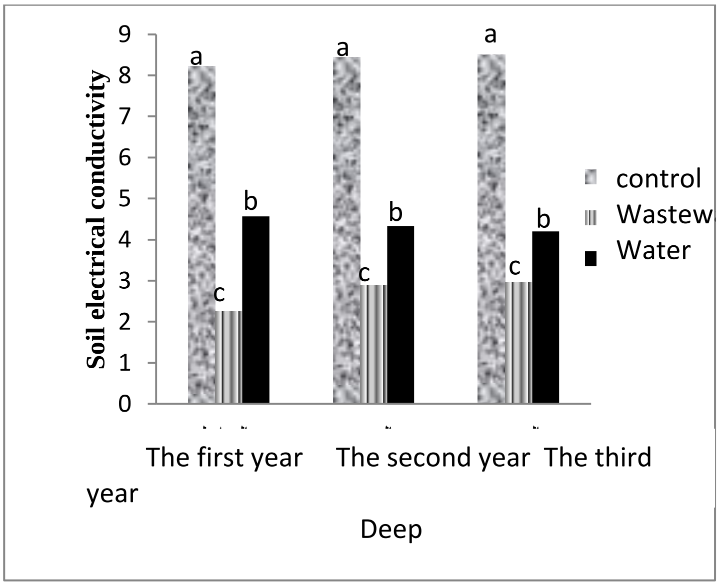

Figure 5 – soil electrical conductivity at 0-30cm depth.

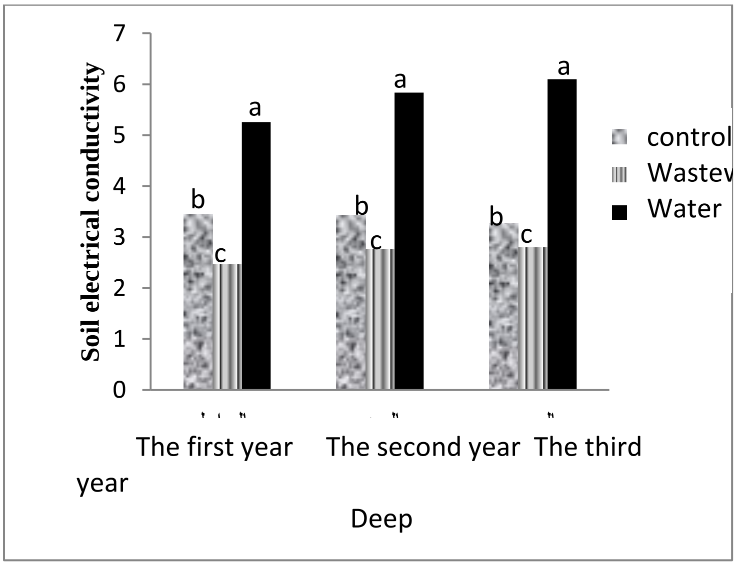

Figure 6 – soil electrical conductivity at 30-60 cm depth

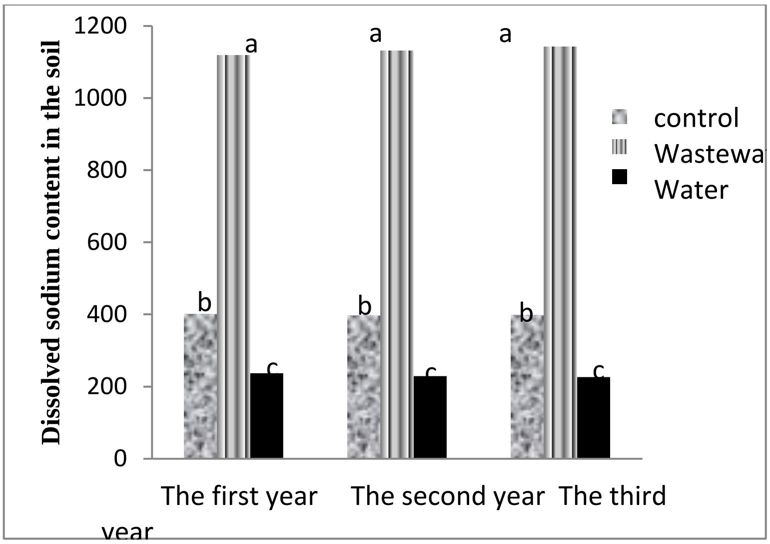

Figure 7 – dissolved sodium content of the soil at 0-30cm depth.

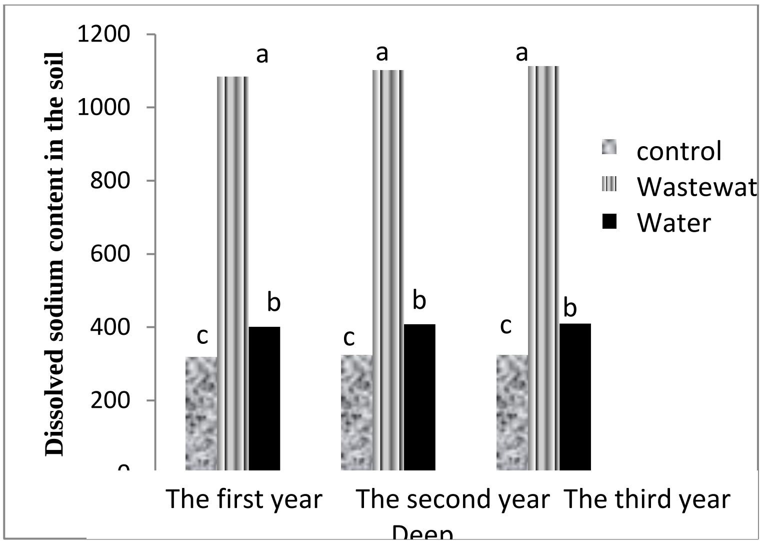

Figure 8 - dissolved sodium content of the soil at 30-60cm depth.

3. Results and Discussion

Results of analysis of freshwater and wastewater samples from Zahesan Wastewater Treatment Plant showed that the amount of boron (B) in the wastewater exceeded the allowable agricultural range but acidity of the effluent was within the allowable range (Table 2). ANOVA results at various depths for the first year showed a significant difference between calcium and magnesium level and electrical conductivity of the soil at 5% significance level. ANOVA and Duncan's test results also showed no significant difference between sodium content and acidity of the soil at 1% significance level. F-values were respectively as 9179.086 and 22.286 (Table 3). Table 4 shows results of analysis of variance relevant to the effect of applied treatment sat different depths in the second year. The results showed that all parameters (calcium and magnesium, acidity and electrical conductivity) were significant at 5% significance level. Sodium content of the soil was significant at 1% significance level. The results of analysis of variance relevant to the effect of applied treatment sat different depths for the third year indicated that levels of calcium and magnesium and electrical conductivity were significant at 5% significance level (F-values were respectively as 180.68 and 4057.279. Figure 1 shows Duncan's test for mean comparison relevant to changes in soil calcium and magnesium content at 0-30cm depth. As observed in Figure 1, no significant different was found between irrigation with freshwater and irrigation with wastewater in the first year. However, a significant difference was found between irrigation with freshwater and irrigation with wastewater in later years. Calcium and magnesium penetration into the soil decreased due to irrigation. Duncan's test results for mean comparison relevant to changes in calcium and magnesium content at 30-60cm depth showed that calcium and magnesium penetration into lower depths of the soil in the first year is higher in irrigation with wastewater than irrigation with freshwater. A significant difference was found between these two treatments at 5% significance level. (Figure 2).

Figure 3 shows mean comparison of soil acidity at 0-30cm depth. The results showed that irrigation with wastewater has increased soil acidity compared to control. There was no difference between the first and second years in irrigation with wastewater in terms of soil acidity. Irrigation with freshwater did not significantly increase soil acidity (Figure 3). Figure 4 shows mean comparison of soil acidity at 30-60cm depth. Irrigation with wastewater increased soil acidity compared to other treatments in the first year at 30-60cm depth. However, no significant difference was observed between irrigation with wastewater and control. No significant difference was also observed between irrigation with freshwater and irrigation with wastewater in terms of soil acidity in the second and the third years (Table 2). Figure 5 shows mean comparison of soil electrical conductivity at 0-30 cm depth. The results showed that soil electrical conductivity has significantly reduced in the first year of irrigation with wastewater and freshwater compared to control. Mean comparison results in terms of electrical conductivity at 30-60cm depth showed that the highest electrical conductivity belonged to irrigation with freshwater, which increased electrical conductivity in deeper layers compared to surface layers. This was due to increased leaching and transport of salts to deeper layers of the soil (Figure 6). However, so significant changes were observed in electrical conductivity of the soil in irrigation with wastewater at all studied periods at the two depths. According to Figures 5 and 6, lack of leaching and transport of soil elements in the control area caused no significant changes in the soil electrical conductivity. Results of mean comparison at 0-30cm depth in the first year showed a significant difference between studied areas in terms of sodium content of the soil (Figure 7). In addition, results of mean comparison in the first year showed that irrigation with wastewater has increased sodium content of the soil. Figure 8 shows mean comparison of sodium content of the soil at 30-60cm depth. The results showed that irrigation with freshwater has increased sodium content of the soil at 30-60cm depth in the first year. Sodium content has also increased in later years due to irrigation with wastewater.

4. Discussion and Conclusion

Studied wastewater contained significant amounts of nutrients needed by plants. Thereby, wastewater is not only an adequate water supply for irrigation of crops, but also improves soil fertility. PH is the most prominent soil chemical property. Many chemical properties of the soil and consequently plant growth, activity of soil organisms and availability of nutrients to plants depend on soil pH (Ghollarata and Raiesi, 2007; Guidi*et al*., 1983). The results of ANOVA at studied depths showed no significant difference in terms of soil acidity. This can be due to 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 Polyacryl 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 but there was no significant difference between the treatment and control. The results of examining electrical conductivity of soil samples in three years showed the significant effect of irrigation with wastewater in the region at 5% significance level, so that soil electrical conductivity was significantly increased in the areas irrigated with wastewater compared to control. These results are consistent with those results obtained by Zamani*et al*. (2010) who showed that saturated hydraulic conductivity was reduced by adding sewage sludge to the soil. In another experiment, the effect of irrigation with wastewater on soil properties was studied in the northern Isfahan, which was irrigated with wastewater for 9 years. The results of the former experiment showed that wastewater reduced electrical conductivity compared to well water (Shahraki and Mahdavi, 2005). In total, irrigation with wastewater increased total dissolved calcium and magnesium in the soil compared to control.

References

Imam Qoli, M. 2012. Assessment of the effect of urban wastewater in desert land reclamation on some chemical properties of soil and vegetation (Case Study: Segzi Plain in Isfahan). Master thesis. School of Natural Resources in Tehran University.

Hassan Qoli, A. 2002. Using domestic sewage and wastewater ofwastewater treatment plants forirrigation of agricultural products and artificial recharge of underground aquifers, PhD dissertation, Tehran University.

Hosseinpour, A., Haghnia, Gh. M., Alizadeh, A., Fotovat, A., (2008), effect of effluent and urban wastewater on some chemical properties of the soil at different depths in both continuous and intermittent flood conditions. Journal of Irrigation and Drainage, 1 (2), 73-85.

Shahraki, F,R. Mahdavi, R. (2005), effect of irrigation with wastewater on some physical and chemical properties of the soil. Journal of Water and Wastewater. No. 53. pp. 23-29.

Research Deputy of Department of Environment, 1994, Wastewater standards. Publications of Office of Environmental Education.

Zaman, M., Matsushima, M., Chang, S. X., Inubushi, K., Nguyen, L., Goto, S., Kaneko, F., and Yoneyama, T. (2004). “Nitrogen mineralization, N2O production and soil microbiological properties as affected by long term applications of sewage sludge composts.” Biology and Fertility of Soils, 40, 101-109.

Abedi – koupai, j *et al*, 2001. Influence of treated wastewater and irrigation systems on soil physical properties in Isfahan province. ICID International workshop on wastewater reuse management. Sep. 19-20. Seoul, Korea. 165-173.

Guidi, G., M. Pagliai and M. Giachetti. 1983. Modifications of some physical and chemical soil properties following sludge and compost application. Dordrecht, Netherlands.

Ghollarata, M. and F. Raiesi. (2007). the adverse effects of soil salinization on the growth of Trifoliumalexandrinum L. and associated microbial and biochemical properties in a soil from Iran. Soil Biol. Biochem. 39: 1699–1702.

Bahremand, M,.Efyoni, M., Hajabasi, A., Rezainejad, y. (2002). Effect of sewage sludge on soil physical properties, "Science and Technology of Agriculture and Natural Resources. Pp. 1-8. (in Persian).

Zamani, J., Efyoni, M., Khoshgoftarmanesh, A., Eshghizadeh, H. (2010). Effect of sewage sludge plant Pliyakril, municipal solid waste compost and cow manure on soil properties and yield of corn. Journal of Science and Technology of Agriculture and Natural Resources, Soil and Water Sciences. Pp. 154-163. (In Persian).