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Compost' leachate recycling through land treatment and application of natural Zeolite

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Abstract

Background: The entrance of untreated wastewater or disposal leachate to water resources such as surface water, groundwater or irrigation water increases the risk of contaminant accumulation. Removal or deduction of water contaminant concentration is then crucial before entering water to the natural resources or its transfusion directly to the soil as irrigation water. Four studies were carried out in a pilot plant to evaluate the effect of natural zeolite to decrease chemical and biological index of compost factory leachate. Land treatment was considered as the main strategy; however, some pounding and column experiment was implemented as well. Wastewater chemical and biological indexes were analyzed. These indexes consisted of Na, K, Mg, Ca, Co_3, HCO_3, Ni, Cd, Pb, Cr, chemical oxygen demand (COD), fecal coliform and total coliform (TC). In addition, soil was analyzed for EC, pH, cation and anion.

Results: In the first study, three types of zeolite derived from Semnan, Mashhad and Miyaneh mines were tested with four sizes (70, 140, 270 and 840 μm) at 25°C in summer 2007. It was concluded that high value of the cation concentration in the leachate causes neither adsorption of remaining cation nor heavy metals. There was no statistically significant difference between the zeolite sizes and the heavy metal adsorption. The results also showed that the adsorption ratios were 52%, 23% and 40% for Na, Ca and Mg, respectively. In the second study, a loamy sand soil was enriched by adding 5% and 10% of the zeolite. The result uncovered that adding 10% of the zeolite to the soil brings about more elements' absorption in comparison to application of the 5% zeolite. Irrigation with the leachate reduced soil specific yield significantly. In the third study, a complete randomized design experiment was used with six treatments (two kinds of soil, loamy sand and clay loam, and three levels of zeolite, 0%, 5% and 10%) and three replications performed in the lysimeter size. The results revealed that irrigation with the leachate reduces soil bulk density, infiltration rate and saturated hydraulic conductivity. Heavy metals could not be absorbed by loamy sand soil, whereas clay loam soil had a high ability to absorb heavy metals and reduce the salinity. In loamy sand and clay loam soil, 10% zeolite had a significant effect on heavy metals' absorption. The result of subsequent study (the same setup as the third study) exhibited the fact that the COD was significantly decreased by application of 5% zeolite, whilethis reduction occurred *via* applying 10% of zeolite in TC.

Conclusions: In short, this research indicated that the wastewater can be treated in a simple, economically process of land treatment through application of a clay loam soil texture with a cation pre-treatment.

Keywords: Zeolite, Heavy metal, Soil, Leachate, Wastewater, Compost

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Background

Compost leachate is potentially a good source of soil fertility improvement. However, high biological and chemical pollutions negatively influence this exploitation. Heavy metals are considered as a major group of these potential contaminations. To remove these pollutions, land treatment is a very cheap method, which is also suitable for leachate application in agriculture. Because of leachate quality, land treatment application requires more investigation in order to identify the best leachate purification condition. Municipal wastewater land treatment system that was started in the late 1880 s to early 1900s has been constantly modified over the time to address this phenomenon and to successfully operate as an effective treatment system (Robert 2004). Total land treatment systems in the USA were distinguished 304 units in 1940, and this number rose to 571 units in 1972 (U.S. Environmental Protection Agency 1981). Land treatment was assumed as the most effective alternative solution in the USA from 1980 to 1905 and was applied by many communities along with sewage treatment (Robert 2004). In Melbourne, Austria, land filtration occurs in 3,833 ha of the farms annually and is able to treat an average of 30 Mm^3 of sewage (about 60%). The land filtration system consists of the periodic application of wastewater on permeable soil and relies on purification by passage of leachate through the soil matrix for treatment purposes (Muneer and Lawerence 2004).

Iran has very limited water resources and, at the same time, possesses very huge non-usage and abandoned lands. A consolidate management system could support and utilize these unemployed lands for wastewater treatment. Now, the question is whether the soil able to maintain heavy metals and square away nutrients to plants (Thawale et al. 2006).

Zeolites are hydrated aluminosilicates of the alkaline and alkaline earthmetals (Badillo-Almaraz et al. 2003; Bell 2001; Kaya and Durukan 2004; Mumpoton 1999; Nazem 2007; Virta 1998). The framework of zeolite is open and contains channels and cavities where cations and water molecules are located. The channel structure of zeolites is responsible for their function as a molecular sieve but is also important for 'selective' cation exchange. The selectivity of different ions is determined by several factors such as the size and state of salvation of the ions, the charge (Si to Al ratio) and geometry of the framework, the number of cation sites available for occupation inside the framework and the temperature (Nazem 2007). Zeolites with dimension pores of 3 to 10 Å are often called molecular sieves (IRNCID 1999). Clinoptilolite has the chemical formula of $Na_{0.1}K_{8.57}Ba_{0.04}(Al_{9.31}Si_{26.83}O_{72})19.56H_2O$ (Erdem et al. 2004; Mabel et al. 2001). Exchangeable ions such as Na^{+1}, K^{+1}, Ca^{+2} and $Mg^{+2}$are commonly occupied by clinoptilolite (Ackley and Yang 1991). These cations are exchangeable with certain cations in solutions as well as lead, cadmium, zinc and manganese (Erdem et al. 2004). Natural zeolites are good potential materials for water and wastewater treatment. It is due to advantages of low-cost ion exchange and adsorption capability of natural zeolites. In addition, it can be modified and regenerated (Widiastuti et al. 2006). Natural zeolite has high CEC (100 meq/100 g) special clinoptilolite; therefore, the rate of both sorption and ion exchange are higher than any other natural zeolite (Kenderilik et al. 2005; Teracy et al. 1998). The selectivity of zeolite species, such as clinoptilolite and chabazite, for heavy metals based on the ionic radius and dissociation constant was as in the following order: $Pb^{2+} > Ni^{2+} > Cu^{2+} > Cd^{2+} > Zn^{2+} > Cr^{3+} > Co^{2+}$ (Choi et al. 2001; Ok et al. 2007). Ion exchange of a specific cation is strongly influenced by the presence of competitive cations and complexion reagents such as anions (Inglezakis et al. 2003a,b; Inglezakis et al. 2005). The maximum sorption capacity of clinoptilolite toward Cd^{2+} was determined as 4.22 mg/g at an initial concentration of 80 mg/L and toward Pb^{2+}, Cu^{2+} and Ni^{2+} as 27.7, 25.76 and 13.03 mg/g, respectively, at 800 mg/L. The sorption results fitted well to the Langmuir and the Freundlich models. The second one was better for adsorption modeling at high metal concentrations (Sprynsky et al. 2006).

Every day, almost 500 tons of garbage are processed in Isfahan Organic Fertilizer Factory (IOFF) and are transformed to compost. This process produces about 40 cubic meters of leachate.

The objectives of these four studies then, were to investigate the power of the clinoptilolite to decrease chemical and biological index of the compost factory's leachate, while the focus of the study was on land treatment.

Methods

First study

The main objective of the first study was evaluation of the HM (Pb, Ni, Cd and Cr) and cation (Na, Ca and Mg) adsorption by a three Iranian natural zeolites (extracted from Miyaneh, Mashhad and Semnan) where Table 1 shows the zeolite properties. The statistical design was factorial with two levels, pounding time and zeolite size. The first level had three pounding time values(70, 90 and 110 min), and the second one had four value sizes (70, 140, 270 and 840 μm). The experiment design was completely randomize with twelve treatments and three replications.

The 10 g of three Iranian natural zeolites was milled to pass a 0.5-mm stainless steel sieve for chemical analysis. Then, these samples with 500 ml of leachate (Table 2) were placed in an orbital shaker (3,500 rpm) and were allowed to be equilibrated for three values of pounding times (70, 90 and 110 min). After this step, they were

Table 1 Zeolite chemical properties of three Iranian natural zeolites

Zeolite	SiO_2	Al_2O_3	CaO	K_2O	Na_2O	Fe_2O_3	MgO	TiO_2	MnO	P_2O_5	LOI	CEC
Semnan	66.5	11.8	3.1	2.1	2	1.3	0.8	0.3	0.04	0.01	12	100
Miyaneh	65	12.2	2.3	3	1.8	1.5	0.1	0.03	0.04	0.01	12	110
Mashhad	68.04	10.14	0.97	1.15	4.31	2.04	1.03	0.31	0.01	0.04	1.94	150

These zeolites were extracted from Miyaneh, Mashhad and Semnan (Afrand Touska Company, Tehran, Iran in 2007). CEC, Cation exchange capacity; LOI, Loss of ignition.

Table 2 Primary chemical analysis of input leachate

SAR	pH	EC (dS/m)	Cl^- (meq/L)	HCO_3 (meq/L)	Na^+ (meq/L)	Ca^{2+} (meq/L)	Mg^{2+} (meq/L)	TDS (mg/L)	TSS (mg/L)	Cr^{3+} (mg/L)	Cd^{2+} (mg/L)	Pb^{2+} (mg/L)	Ni^{2+} (mg/L)
11.88	4.9	33.55	295	695	225	416	301	58400	9026	0.74	1.24	4.28	4.43

SAR, Sodium adsorption ratio; EC, Electrical conductivity; TDS, Total dry solid; TSS, Total suspended solid.

placed in the centrifuge for 5 min. Thereafter, suspensions were centrifuged at 3,500 rpm for 5 min and the supernatant were filtered through Whatman no. 42 filter paper (Whatman Ltd., India), and then sub-samples were digested by acid. The parameters of analysis were measured in the solution before and after the contact with zeolite and calculated adsorption rate (AR) as well.

Results and discussion

Tables 3 and 4 show that Na has desorbed from zeolite to solution samples. This desorption was significant for Miyaneh and Mashhad samples ($p = 0.01$) and for Semnan zeolite case ($p = 0.05$), which could be due to zeolite structure.

The Ca and Mg with high concentration were absorbed by the zeolite significantly. The results revealed that the pounding time was significant for the cation adsorption. It could be seen that the maximum cation adsorption occurred in 110 min for Miyaneh and Semnan cases, and 90 min for Mashhad zeolite. The results also indicated that the AR of Pb ($p = 0.01$), Cr and Ni ($p = 0.05$) was significant in Mashhad zeolite, whereas it was not significant for the two remaining zeolites. In general, heavy metals' adsorption was too low in all zeolites. It can be concluded that high value concentration of the cations like Na, Cl and Mg might prevent the zeolite to absorb heavy metals.

As it is exhibited in Table 4, the results show that the zeolite size had no significant effect on heavy metals' adsorption; nonetheless, the 140- and 270-μm sizes had more AR. Maximum heavy metal adsorption happened in 70, 110 and 70 to 90 min (pounding time) for the cases of Miyaneh, Mashhad and Semnan zeolite, respectively.

Second study

This study was carried out in IOFF compost, Isfahan, Iran during the summer of 2007. The IOFF's soil and leachate were used for the experiment. In general, soil could be classified as sandy-clay-loam in which the characteristics of soil and leachate are presented in Table 5. The clinoptilolite was employed with a 0.279-mm diameter that was supplied from Semnan mine (center of Iran).

The experiment was conducted in 20 columns. Each column was made from PVC with a 110 and 400 mm diameter and height, respectively. The first lower 50-mm

Table 3 The mean of heavy metal removal percentage of leachate at three value of pounding time

Zeolite	Time (min)	Na	Ca	Mg	EC	pH	Pb	Cd	Ni	Cr
Miyaneh	70	10.3	4.08	28.4	−1	1.01	−67	8.2	15	4.5
	90	9.6	11.4	9.4	0.71	0.2	−8.9	13	6.8	4.4
	110	45.5	13.9	8	3.1	−2.2	−10	3.9	3.6	−9
Mashhad	70	−16	5.7	16.3	1.5	0.43	3.71	19	7.7	17
	90	−18	2.3	31.7	−0.1	0.32	4.9	18	2.79	12.3
	110	−6	8.8	−3.4	1.31	0.25	17.5	6.4	23.6	32.1
Semnan	70	14	29.9	7.5	−1	0.22	2.45	21	3	26
	90	13	2.7	11.7	3.3	0.25	3.36	24	9.6	8.6
	110	20	6.5	20.9	1.75	0.11	8.76	18	7.9	7.7

EC, Electrical conductivity.

Table 4 The mean of heavy metal removal percentage of leachate at four value sizes

Zeolite	Size (μm)	Na	Ca	Mg	EC	pH	Pb	Cd	Ni	*r*
Miyaneh	840	−20.7	10.3	11	0.93	0.19	13	8.6	7.11	1.8
	270	−24	8.03	16	1.8	0.33	5.5	8.2	8.2	10.1
	140	−22.8	9.9	10	0.23	−0.06	10.4	7.01	9.2	−11
	70	−19.6	10.9	22	0.66	0.96	14.4	9.92	9.3	1.3
Mashhad	840	−15.8	3.9	9	−0.4	−0.33	6.4	8.3	10.6	11.8
	270	−12.4	7.1	1.9	0.18	−0.15	11.9	17.1	15.1	21.1
	140	−12.8	6.5	6.5	0.23	−0.3	8.05	12.3	11.6	24
	70	−14	4.8	−0.8	0.1	−0.55	8.43	21.2	8	24
Semnan	840	−14.5	11.9	8	−1.5	0.18	2.53	14.8	7.3	8.8
	270	−16.8	16.7	14	−0.8	0.33	7.2	23.8	4.7	16.8
	140	−16.1	10	21	−1.7	0.17	4.57	15.3	3.7	13.3
	70	−16.1	12.5	10	0.72	0.1	5.13	22.2	11.5	17.9

EC, Electrical conductivity; *r*, ratio.

Table 5 Soil chemical and physical characteristics and IOFF's compost leachate chemical properties

Sample	pH	EC (dS/m)	SAR	OM %	Ni (mg/L)	Pb (mg/L)	Cd (mg/L)	Cr (mg/L)	ρ_s (g/cm^3)	ρ_b (g/cm^3)
Soil	6.7	0.41	2.56	0.17	1.33	2.29	0.12	0	2.37	1.34
Leachate	4.9	33.5	11.9	-	4.44	4.28	1.24	0.73	-	-

EC, Electrical conductivity; SAR, Sodium adsorption ratio; OM, Organic matter; ρb, Specific gravity; ρs, Bulk density.

part of the column was filled with filtered sands. Based on research treatment, the next 250 mm was filled with the soil as it is described below. Again, the next 50 mm of the column was filled with filtered sand, and the remaining 50 mm was left empty for irrigation. Then, leachate was used to irrigate the soil columns every 3 days. The total number of irrigation events and the depth of irrigation were 12 times and 20 mm, respectively. A completely randomized block design was employed with four treatments and four replications. Four treatments were implemented as the following: T1, sandy clay loam soil irrigated with fresh water (control); T2, sandy clay loam soil irrigated with leachate; T3, sandy clay loam soil mixed with 5% of the clinoptilolite irrigated with leachate; and T4, sandy clay loam soil mixed with 10% of the clinoptilolite irrigated with leachate. Four columns were randomly selected for the soil initial condition measurement. The rest of columns (16) were used for the analysis at the end of period. Soil samples of the columns were analyzed in two different depths (0-10 cm and 10-25 cm). Drained water was collected from the columns, and soil analysis was conducted based on disturbed soil.

Results and discussion

The results demonstrate that in soil column the salinity reduction (EC) value of drained water was decreased compare to the input value (Table 6). It illustrates that irrigation with the leachate has significantly increased the soil EC in all treatments (Table 7). It concludes that adding zeolite to the soil increases solution adsorption into the topsoil and prevents it to be leached towards subsoil. In addition, the results show that irrigation with leachate increments soil OM percentage in all treatments ($p = 0.01$).

The findings also explain that the maximum adsorbed concentrations of the Ca, Mg and Na were observed in T4. The findings furthermore highlight the fact that HCO_3 was absorbed in topsoil (0-25 cm), while Cl was absorbed in the subsoil (25-40 cm). Again, a significant difference was observed between the treatments ($p = 0.05$). It can be seen also that the concentrations of the elements in drained water rose along with increasing number of irrigation events. The results, likewise, reveal that adding zeolite to the soil neutralized the soil's pH.

Table 6 presents that the Ca^{2+} concentration in drain water in T4 was lower than T3 and T2 ($p = 0.05$). Also, Ca concentration in drained waters increased with enhancing irrigation events. It is noticeable that the high value cation concentration in the leachate has decreased the soil/clinoptilolite adsorption capacity.

Based on Table 6, the Mg concentration was lower than Ca concentration in drained water. It means that soil and zeolite adsorbed Mg more than Ca in leachate treatments. The Mg absorption from leachate was significantly different ($p = 0.01$) between the treatments based on Duncan test except at the end of period.

It indicated that high concentration of cations like Ca^{2+}, Mg^{2+} and Na^+ and anions such as Cl^- and HCO_3 in the leachate saturated the cation exchange capacity of related zeolite. It shows that zeolite can accommodate a wide variety of cations (positive ions), such as Na^+, K^+, Ca^{2+}, Mg^{2+}, etc. These positive ions are held rather loosely and can be readily exchanged with others in a contact solution (Mumpoton 1999).

It can be concluded that irrigation with the leachate has decreased drain water's SAR in all treatments (Table 6). It has a significant difference ($p = 0.05$; based on the Duncan test). Briefly, in order to raise the sandy clay loam ability in this research, different levels of zeolite were blended with soil, and the capacity of heavy

Table 6 Chemical properties of output leachate

Mean of total period	T	Sy (%)	pH	EC (dS/m)	Ca (meq/L)	Mg (meq/L)	Na (meq/L)	HCO_3 (meq/L)	Cl (meq/L)	Ni (mg/L)	Pb (mg/L)	Cd (mg/L)	Cr (mg/L)	SAR
	1	33.45	7.3	1	7.73	6.63	7.12	30.17	20.42	0	0	0	0	2.86
	2	34	6.6	27.37	212.3	148.7	148.1	463.97	198.8	1.75	1.35	0.11	0	10.78
	3	30	6.38	26.82	213.2	130.4	148.3	432.97	188.1	1.71	1.35	0.12	0	10.94
	4	25.75	6.17	26.32	201.2	104	147	374.31	176	1.52	1.25	0.1	0	10.43

T, Treatment; Sy, Specific yield; EC, Electrical conductivity; SAR, Sodium adsorption ratio.

Table 7 Chemical and physical properties of soil treatments at the beginning and end of experiment

Time	Depth	T	pH	EC	Ca	Mg	Na	HCO_3	Cl	Ni	Pb	Cd	Cr	OM	SP	Lime	SAR	ρb	ρs
	(cm)			(dS/m)			(meq/L)				(mg/L)			(%)				(g/cm^3)	
Before	0–10	1	6.6	0.41	1.4	0.4	2.84	24	30	1.25	2.9	0.1	0	0.22	22.9	69	2.4	1.1	2.3
		2	7.1	0.25	1.4	0.4	2.18	15	30	1.12	2.5	0.1	0	0.17	33.2	70	2.3	1.3	2.4
		3	6.9	0.37	1.4	0.4	2.84	20	30	1.57	2.4	0.1	0	0.15	22.4	60	3	1.4	2.5
		4	6.5	0.28	1.4	0.5	2.18	30	10	1.2	2.3	0.1	0	0.24	23.7	59	2.2	1.3	2.3
	10–25	1	6.8	0.38	1.4	0.4	2.18	20	30	1.65	2.6	0.1	0	0.19	21.7	68	2.3	1.3	2.5
		2	7	0.31	1.4	0.4	2.18	20	20	1.55	1.8	0.1	0	0.17	21.5	68	2.3	1.4	2.3
		3	6.6	0.36	1.4	0.5	2.84	25	30	1.6	2	0.1	0	0.1	23.1	58	3	1.5	2.2
		4	6.5	0.38	1.4	0.4	2.84	30	10	1.67	1.8	0.1	0	0.14	23.5	58	3	1.4	2.4
After	0–10	1	7.8	0.79	7.7	18.7	20.1	10	33.3	1.85	2.7	0.1	0.4	0.24	23.1	46	5.5	1.2	2.3
		2	7.9	9.87	8.4	149	86.9	50	76.7	1.71	2.5	0.2	0.4	1.56	22.1	46.3	9.8	1.2	2.3
		3	8.1	13.6	9.7	177	97.6	50	117	1.73	2.9	0.1	0.3	1.29	25.8	46.3	10	1.5	2.6
		4	7.9	14.9	27	156.7	97.6	63	143	1.46	2.9	0.1	0.2	1.71	24.4	46.6	11.4	1.3	2.3
	10–25	1	7.6	0.78	6.4	18.73	19.6	13.3	50	1.25	2.7	0.1	0.4	0.25	22.3	46.7	5.6	1.3	2.3
		2	8.3	16.8	11	144	86.9	23.3	86.7	1.72	2.7	0.1	0.3	0.96	24	47.3	5.9	1.5	2.3
		3	8.4	13.9	11	117.1	97.6	33.3	127	1.63	2.5	0.1	0.2	1.06	22.2	49	10	1.4	2.2
		4	8.05	11.5	20.4	112.4	86.9	30	170	1.43	2.3	0.1	0.2	1.44	25.1	48	10.7	1.3	2.3

T, Treatment; EC, Electrical conductivity; OM, Organic matter; SP, Saturation percentage; SAR, Sodium adsorption ratio; ρb, Specific gravity; ρs, Bulk density.

metals' absorption in the soil was estimated. According to the results of this research, high concentration of cations in the leachate filled the cation exchange capacity of the zeolite. Therefore, heavy metals such as Ni, Pb, Cd and Cr were all absorbed by the soil with suitable values; however, soil enrichment using certain percentages of this research (5% and 10%) could not significantly enlarge adsorption capacity.

Third study

The main objective of this study was to investigate the possibility of leachate remediation by land and the effects of leachate application on some specified soil physical properties. Hence, a complete randomized block design experiment with six treatments was applied (A0, loamy sand soil (Table 8); A5, loamy sand soil mixed with 5% zeolite; A10; loamy sand soil mixed with 10% zeolite; B, clay loam soil (50% Organic Fertilizer Factory mixed with 50% Khaton-Abad farm); B5, clay loam soil mixed with 5% zeolite; and B10, clay loam soil mixed with 10% zeolite), and three replications were performed in 18 PVC soil columns filled with treatment soils (60-cm diameter and 100-cm height). Clinoptilolite zeolite was mainly taken from Semnan City. For irrigation of columns, the leachate extracted from Isfahan Organic Fertilizer Factory compost was utilized. During the research period, the soil columns were irrigated 16 times on a weekly basis. The water added to the soil columns was 5 cm each time.

Table 8 Chemical properties of two kinds of soils used in experimental studies

OC (%)	pH	EC(ds/m)	Texture
0.1	6.85	0.34	Loamy sand
0.48	6.54	0.38	Clay loam

EC, Electrical conductivity; OC, Organic carbon.

Results and discussion

The results showed that adding zeolite to the treatments increased the bulk density against irrigation, while the leachate caused reduction of the bulk density. After irrigation with leachate, high concentration of Na^+ dispersed the soil; nevertheless, it was not significant in all treatments.

Adding zeolite to loamy sand and clay loam soils reduced infiltration and saturated hydraulic conductivity. It sounds that the particles of zeolite lied between pores of the soil. As a result, heavy metals such as Ni, Pb, Cd and Cr could not be absorbed by loamy sand soil (Figure 1) and the EC was not significant ($p = 0.01$) in this soil, whereas clay loam soil had a high ability to absorb heavy metals and reduce the salinity. In loamy sand soil, zeolite (10%) had a significant aptitude in absorption of heavy metals and reduction of salinity; nevertheless, in clay loam soil, zeolite did not have any positive effect on the soil.

Fourth study

The setup of this study was the same as the third study. Some chemical pollution indexes such as Na, Ca, Mg, chemical oxygen demand (COD), fecal coliform and

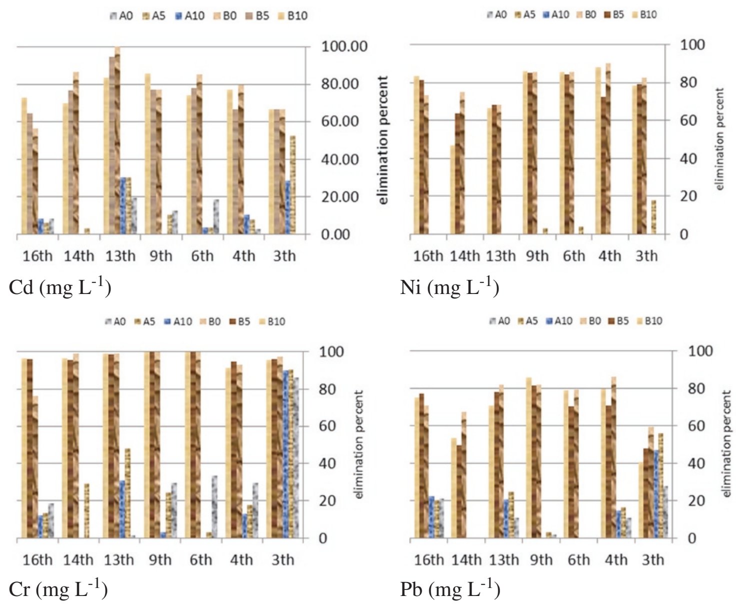

Figure 1 Concentration of absorbed heavy metals (mg/L) by loamy sand soil and clay loam soil.

total coliform (TC) were then analyzed at this step. The treatments were similar to the third study.

Results and discussion

Effects of soil texture and zeolite on chemical oxygen demand (COD)

The leachate derived from the compost had a strong brown color, indicating that it is an organic material. The mean value of COD was estimated equal to 100 g/L during the experimental period. In addition, above mentioned leachate existed more in the clay loam soil than the loamy sand soil. Because clay loam soil has higher CEC than other soils, it could absorb more OM from the leachate. On the other hand, due to small pores of the clay loam, the air condition is poor.

Loamy sand soil mixed with 5% zeolite had better removal efficiency than clay loam soil mixed with zeolite. The results showed that adding zeolite to the clay loam does not have any significant effect on COD. Its looks depend to high-level adsorption of OM by this treatment.

Effect of soil texture and zeolite on total coliform (TC)

Clay loam has higher elimination capacity than loamy sand soil because clay loam soil has lower permeability rate than the other one. On one hand, total coliform was absorbed by the soil of the column and decomposed by nematode and protozoa. On the other hand, specific surface of clay accelerate coliform adsorption from the leachate. Sandy loam with zeolite had high significant impact on removal capacity of TC, but the clay loam was the opposite.

Effects of soil texture and zeolite on Na, Ca and Mg of the leachate

Clay loam soil showed better performance on Na, Ca and Mg adsorption than the sandy loam soil. The reason is that clay loam soil has higher CEC than the other one. Soil and zeolite particles tend to adsorb these bivalent cations than Na, and a significant difference was recognized between their adsorptions by soil and zeolite particles ($p = 0.05$). Clay loam soil mixed with 10% zeolite has the highest cation elimination capacity than other treatments because this soil has most specific surface and CEC.

Conclusions

According to the results of this research, following conclusions can be presented: First, study revealed that the AR in Mashhad zeolite was significant for Pb ($p = 0.05$) and Cr/Ni ($p = 0.05$). Nevertheless, it was not significant for the two remaining zeolites. Zeolite size had no significant effect on the heavy metals' adsorption; however, the 140 and 270-μm size had more AR. Maximum heavy metals' adsorption happened in 70, 110 and 70-90 min (pounding time) for Miyaneh, Mashhad and Semnan zeolite, respectively. Maximum cation adsorption occurred in 110 min for Miyaneh and Semnan zeolite, and 90 min for Mashhad zeolite.

In the second study, high concentration of cations of the leachate filled the cation exchange capacity of the zeolite and soil, so heavy metals such as Ni, Pb, Cd and Cr were absorbed by the soil negligibly. Notwithstanding, soil enrichment with 5% and 10% zeolite could not significantly enhance the adsorption capacity. Additionally, the majority of heavy metals were absorbed in the topsoil (0-10 cm). High concentration of cations and anions in the leachate saturated soil CEC and also absorbed anions and cations by soil/zeolite. Furthermore, adding 10% zeolite to the soil (T4) resulted in more absorption. Heavy metals, Ca and Mg, were absorbed in topsoil, but Cl^- was mainly absorbed in subsoil than the topsoil. Na^+, SAR, HCO_3 and Cl^- concentrations in drained water were increased with increased number of irrigation events.

In the third study, adding zeolite to the treatments enhanced the bulk density and reduced infiltration and saturated hydraulic conductivity, whereas irrigation with the leachate caused reduction of the bulk density. Clay loam soil had a high ability in absorption of heavy metals and reduction of salinity. Similarly, loamy sand soil mixed with 10% zeolite had a significant impact on absorption of heavy metals and reduction of salinity.

Eventually, in the fourth study, adding zeolite to clay loam had no significant effect on COD. It sounds dependent to high-level adsorption of OM by this treatment. Sandy loam with zeolite had high significant impact on removal capacity of TC. Oppositely, clay loam had no impact on removal capacity of TC. Clay loam implemented better performance than the sandy loam soil on Na, Ca and Mg adsorption. The reason could be the fact that this soil had most specific surface and CEC.

Abbreviations
EC: Electrical conductivity; OM: Organic matter; SAR: Sodium adsorption ratio; ρb: Specific gravity; ρs: Bulk density; T: Treatment; Sy: Specific yield; TDS: Total dry solid; TSS: Total suspended solid; CEC: Cation exchange capacity; LOI: Loss of ignition.

Competing interests
The authors declared that they have no competing interest.

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Authors' contributions
ZN, LA, SM, JM, and MZ collected the lab/experimental data. S-HT, PN and MH carried out the supervision on the data analysis and revised them. SH, MA, HBH and EL revised the thesis. MB and HA helped in laboratory analysis. All authors read and approved the final manuscript.

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