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Effect of Iron Slag Enriched Cow Manure, Zeolite and Pumice on the Sunflower Pb Uptake in a Soil Irrigated With Wastewater of Battery Factory

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Abstract

Background: In order to optimize the use of industrial wastewater, proper management practices should be applied for wastewater treatment. Thus, this study was done to evaluate the effect of iron slag enriched cow manure, zeolite and pumice on the sunflower Pb concentration in a soil irrigated with wastewater of battery factory.

Methods: In this descriptive study, treatments consisted of applying iron slag (0, 1 and 2 % (W/W)) enriched cow manure at the rates of 0 and 30 t/ha, using zeolite (0 and 2 % (W/W)) and pumice (0 and 8 % (W/W), and sunflower irrigation with the wastewater of battery factory mixed with well water with the ratio of 1:1 and 1:2 (water/wastewater). After 60 days, the plant was harvested and the concentration of Pb and Fe was measured using atomic absorption spectroscopy. The SOD enzyme activity was also determined.

Results: Application of 2% zeolite and 8% (W/W) pumice significantly decreased the Pb concentration of the soil irrigated with the wastewater at the ratio of 2:1 (wastewater/water) by 8.1%, respectively. The plant Pb concentration was also increased by 11.2 and 13.3%, respectively. The SOD enzyme activity showed a similar trend with the plant Pb concentration. Enrichment of cow manure with iron slag significantly decreased the Pb concentration of the plant that was irrigated with the wastewater at the ratio of 2:1 (wastewater/water) by 11.3%

Conclusion: Iron slag enriched cow manure, pumice and zeolite significantly decreased the soil and plant Pb concentration of the soil and plant that was irrigated with wastewater.

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Introduction

Regarding the increasing population growth, the consequent increase of water demand and limited water resources, the importance of recycling wastewaters as a reliable resource of water supply and protection of the environment become more evident. In spite of the fact that more than 80 percent of the earth surface is covered by water, freshwaters constitute only a small part of this amount.[1] Freshwaters are not uniformly distributed on the earth, and only 62 percent of the freshwaters of lakes, rivers, and groundwater are available to human.[2, 3]

Renewable freshwater cannot supply agricultural, industrial, and urban consumption needs. Thus, humans will seek for other alternatives such as recycled wastewater, urban wastewater, desalinated sea water, and other marginal-quality waters. As wastewater is considered as polluted freshwater and the cost of treating it for irrigation is far less than that of irrigation by other marginal-quality waters, wastewater reuse is considered as a way of compensating for some water needs. Therefore, wastewater reuse can provide a reliable resource for dry years.[4, 5]

On the other hand, due to poisoning effects and accumulation in the food chain, wastewater pollution is currently important from the environmental aspects. One of the main sources of heavy metal pollution is the existence of different industries such as battery manufacturing that can cause the release of lead. Thus, penetration of wastewater into th soil can lead to accumulation of large amounts of heavy elements in soil depending on the wastewater pollution degree.[6-8] It can cause environmental risks in long term. Lead and some other heavy metals such as cadmium and chrome are declared as toxic pollutants by US Environmental Protection Agency. According to the standards reported by the Iranian environmental standard organization, the maximum standard concentration of Pb is determined as 1 mg/l.

Regarding the increasing use of sewage and sludge resulting from wastewater treatment for irrigation, especially in suburbs in developing countries, it is important to investigate the penetration of heavy elements into the soil in terms of accumulation of toxins in the soil, absorption of them by plants, and groundwater pollution.[7, 9] Therefore, it is extremely important to investigate and find proper solutions for wastewater treatment for its use, especially in arid and semi-arid regions. One of the common methods of wastewater treatment is physicochemical method (including sequestration neutralization by lime and sodium carbonate). It is worth mentioning that in spite of high efficiency, such methods have some disadvantages such as high cost of chemicals and equipment and the probability of pollution of new compounds as a result of incomplete reactions between heavy metals and chemicals.[10, 11]

It is worth mentioning that using compounds with a high specific surface area such as zeolite or pumice in wastewater treatment can significantly increase the absorptive capacity of the soil and decrease the heavy metal pollution resulteing from penetration of wastewater into the soil.[12, 13] Zavvar Mousavi et al. evaluated the effect of Semnan natural zeolite on removal of heavy metal in wastewater and concluded that zeolite could be used as an adsorbent for removal of some heavy metals ion from wastewater; they reported that the adsorption percentage increased with the increasing amount of the sorbent. According to their results, the optimum metals adsorption percentage was 99.2, 85.8, 66 and 47% for Pb(II), Cu(II), Zn(II) and Cd(II), respectively. The optimum zeolite amount was selected as 1g per 100 mL solution containing heavy metal ions.[14]

Considering the fact that in the arid and semiarid regions of the country, the amount of organic matter is low, it is necessary to use organic additives such as cow manure. On the other hand, due to the lack of water resources in these areas, irrigation with renewable resources such as wastewater can contribute to the plant growth in these areas. However, wastewater is often contaminated with heavy metals and needs to be treated. Using organic amendments with high specific surface area such as zeolite or pumice in the soil can help to decrease the toxicity of heavy metal wastewater.[15, 16] On the other hand, enrichment of cow manure with iron slag can improve the nutritional conditions of the plant and contribute to higher plant growth and less heavy metal uptake. Thus, this research was conducted to evaluate the effect of iron slag enriched cow manure, zeolite and pumice on the sunflower Pb uptake in a soil irrigated with wastewater of battery factory.

Materials and Methods

In order to treat the wastewater of the battery factory and reuse it for irrigation water, this experiment was designed to investigate the effect of iron slag enriched cow manure, zeolite and pumice on the sunflower Pb uptake in the soil irrigated with wastewater of battery factory as greenhouse experiment with three replicates. This study was done as a factorial experiment in the layout of randomized and completely blocked design treatments (48 treatments) consisting of applying iron slag (0, 1 and 2 % (W/W)) enriched cow manure at the rates of 0 and 30 t/ha, applying zeolite (0 and 2 % (W/W)) and pumice (0 and 8 % (W/W). The sunflower plant was used in this study and irrigated with the wastewater from a battery industry with the Pb concentration of 200 mg Pb/lit that was mixed with well water with the ratio of 1:1 and 1:2 (water/wastewater).

For doing this research, a type of non-saline soil with the low organic carbon was selected. Then, the soil was amended with zeolite and pumice at the mentioned rates. Afterwards, the iron slag enriched cow manure was added to the soil at the rates of 0 and 30 t/ha and incubated to equilibrium for two weeks. Selected properties of the soil and cow manure used in this experiment are presented in Table 1.

Then, the plastic pots were filled with 5 kg soil amended with cow manure. Three seeds of sunflower *(Helianthus annuus* L.) were sown on the treated soil in the pots and irrigated with diluted wastewater at the ratio of 1:1 and 2:1 (wastewater/water). After two weeks, the seedlings were thinned to one plants per pot and grown for 8 weeks. It should be noted that for

Table 1: Selected properties of soil and vermicompost used in the study

Soil parameter	Amount	Cow manure parameter	Amount
pH	7.3	pH	8.1
EC (dS^{-1})	0.8	EC (dS^{-1})	14.3
Organic Carbon (%)	0.2	Organic Carbon (%)	22
Soil Texture	Loamy	Total N (%)	1.3
Calcium Carbonate Equilibrium (%)	5	Total Pb (mg kg^{-1})	ND
Total Pb (mg kg^{-1})	ND	Total Cd (mg kg^{-1})	ND
Total Cd (mg kg^{-1})	ND		
CEC (c mol/kg soil)	10.1		

ND: Not detectable by atomic absorption spectroscopy (AAS)

prevention of the loss of nutrients and trace elements out of the pots, plastic trays were placed under each pot and the drained water was returned to the pot. After 60 days, the plants were harvested and the Pb of the soil and plant was measured, using atomic absorption spectroscopy (Perkin-Elmer model 3030). In addition, the plant Fe concentration was also measured.[17]

Superoxide dismutase activity (SOD, EC 1.15.1.1) was determined as A550 in 50 mM phosphate buffer, 0.1 mM EDTA, 1 mM NaCN, 0.01 mM cyt c, and 1 mM xanthine, pH 6.0.[18] A unit of SOD is defined as the amount of enzyme required to cause 50% inhibition of cytochrome c reduction.

The statistical analyses were performed according using ANOVA through SAS V.9.1 software. The mean differences were considered according to the least significant difference (LSD test). A P value of 0.05 was considered as significant.

Results

Applying pumice, zeolite and iron slag enriched cow manure had a significant effect on decreasing the soil Pb availability; the results of this study showed that the greatest soil Pb availability belonged to the soil without receiving any organic amendment and irrigated with Pb polluted waste water (150 mg Pb/lit) (Table 2). Application of diluted wastewater at the ratio of 1:1 (water/wastewater) compared to undiluted wastewater significantly decreased the soil Pb concentration by 8.1%. However, applying zeolite and pumice also had a significant effect on reduction of the soil Pb concentration. Based on the results of this study, application of 2 and 8% (W/W) zeolite and pumice significantly decreased the soil Pb concentration by 11.3 and 14.2%, respectively. On the other hand, adding 2% (W/W) iron slag to the soil significantly decreased the Pb concentration in the soil that received 2% (W/W) zeolite.

Adding different ratio of wastewater to water had significant effect on plant Pb concentration (Table 3). Based on the results of this study, the greatest plant Pb concentration belonged to the plants that were irrigated with the wastewater (2:1 wastewater to water), while the lowest that was measured in the plants which was irrigated with an equal ratio of wastewater and water. Increasing the ratio of water to waste water from 1:2 to 1:1, the Pb concentration of the plants grown in the zeolite (2% (W/W)) amended soil significantly decreased by 6.8%. Application of 2 and 8% (W/W) zeolite and pumice significantly decreased the plant Pb concentration by 12.3 and 14.8%, respectively. In addition, using iron slag had adverse effect on plant Pb concentration. Based on the results of this study, enrichment of cow manure with iron slag at the rates of 1 and 2 % (W/W) significantly

Table 2: The effect of iron slag enriched cow manure, zeolite, pumice and wastewater to water ratio on soil Pb concentration (mg/kg soil)

Iron slag (%)	Pumice (%)	Zeolite (%)	Cow manure (t/ha)			
			0		30	
			Wastewater to water ratio		Wastewater to water ratio	
			1:1	2:1	1:1	2:1
0	0	0	55.3e*	59.8a	57.5c	58.5b
1			52.8g	58.6b	55.4e	57.2c
2			50.1i	57.4c	53.2f	55.6e
0		2	50.2i	57.1c	51.2h	53.4f
1			48.4k	55.4e	50.6i	52.1g
2			46.8m	53.4f	48.6k	50.7i
0	8	0	47.8l	56.4d	49.3j	55.2e
1			44.5o	53.1f	47.8l	52.7g
2			43.3p	50.9i	45.5n	48.3k
0		2	45.6n	55.2e	47.7l	53.2f
1			40.1q	51.7h	43.1p	49.7j
2			37.6r	48.5k	40.9q	45.4n

*Data with the similar letters are not significantly different (P=0.05)

Table 3: The effect of iron slag enriched cow manure, zeolite, pumice and wastewater to water ratio on plant Pb concentration (mg/kg)

Iron slag (%)	Pumice (%)	Zeolite (%)	Cow manure (t/ha)			
			0		30	
			Wastewater to water ratio		Wastewater to water ratio	
			1:1	2:1	1:1	2:1
0	0	0	50.2e*	55.8a	51.4d	53.6b
1			48.7g	53.9b	50.8e	51.8d
2			46.8i	52.5c	48.9g	50.5e
0		2	47.4h	53.8b	49.2f	52.4c
1			45.5j	51.6d	47.4h	50.3e
2			43.4l	50.5e	46.7i	48.7g
0	8	0	44.4k	50.3e	47.3h	48.4g
1			43.2l	49.1f	44.5k	45.8j
2			40.5m	48.4g	44.7k	44.7k
0		2	40.7m	48.3g	44.2k	45.2j
1			37.5m	47.6h	43.6l	44.5k
2			34.1n	45.4j	40.2m	43.2l

*Data with the similar letters are not significantly different (P=0.05)

Table 4: The effect of iron slag enriched cow manure, zeolite, pumice and wastewater to water ratio on plant biomass concentration (g)

Iron slag (%)	Pumice (%)	Zeolite (%)	Cow manure (t/ha)			
			0		30	
			Wastewater to water ratio		Wastewater to water ratio	
			1:1	2:1	1:1	2:1
0	0	0	4.33i*	4.11k	4.53g	4.23j
1			4.45h	4.22j	4.64f	4.33i
2			4.56g	4.31i	4.75e	4.46h
0		2	4.42h	4.25j	4.61f	4.34i
1			4.53g	4.36i	4.74e	4.47h
2			4.67f	4.45h	4.84d	4.54g
0	8	0	4.57g	4.34i	4.71e	4.52g
1			4.69f	4.43h	4.85d	4.62f
2			4.78e	4.61f	5.03b	4.71e
0		2	4.72e	4.61f	4.87d	4.73e
1			4.89d	4.77e	5.00b	4.83d
2			4.95c	4.89d	5.15a	4.93c

*Data with the similar letters are not significantly different (P=0.05)

decreased the plant Pb concentration by 11.3 and 14.5 %, respectively.

The greatest plant biomass was observed in the plant grown in the soil which was treated with iron slag enriched cow manure and irrigated with the lowest ratio of water to wastewater, while the lowest belonged to the plants watered by the equal ratio of water and wastewater (Table 4). The application of 2% (W/W) zeolite in the soil irrigated with the 2:1 and 1:1 ratio of wastewater to water significantly increased the plant biomass by 11.6 and 8.1%, respectively. Additionally, applying pumice showed similar results. For instance, using 8% (W/W) pumice increased the plant biomass by 13.6%. In addition, enrichment of cow manure with 1 and 2% (W/W) iron slag significantly increased the plant biomass by 8.9%. The important result of this study was that the simultaneous application of zeolite and pumice had an additive effect on the wastewater treatment of battery factor. For instance, simultaneous application of zeolite and pumice significantly increased and decreased the plant biomass and plant Pb concentration by 11.3 and 14.3%, respectively.

The greatest plant Fe concentration was measured in the plants cultivated in the soil amended with iron slag enriched cow manure, while the lowest belonged to the plants grown in non-treated soil (Table 5). Applying zeolite and pumice had a significant effect on increasing plant Fe concentration; the results of this study showed that applying 2% (W/W) zeolite and 8% (W/W) pumice significantly increased the plant Fe concentration by 8.8%. In addition, using 30 t/ha cow manure significantly increased the Fe concentration by 7.7% in the plant cultivated in the soil amended with 2% (W/W) zeolite. With increasing the dilution of wastewater from the ratio of 2:1 to 1:1 (wastewater to water), the plant Fe concentration significantly increased. However, the application of cow manure with diluted wastewater had additive effect on increasing plant Fe concentration. Based on the results of this study, plant Fe and Pb concentration had interaction effects. Soil Fe concentration showed similar results (Table 6). Based on the results of this study, the simple

Table 5: The effect of iron slag enriched cow manure, zeolite, pumice and wastewater to water ratio on plant Fe concentration (mg/kg)

Iron slag (%)	Pumice (%)	Zeolite (%)	Cow manure (t/ha)			
			0		30	
			Wastewater to water ratio		Wastewater to water ratio	
			1:1	2:1	1:1	2:1
0	0	0	104.6w*	100.2x	151.9l	147.7m
1			106.5v	104.4w	154.2k	151.6l
2			108.9t	107.2u	160.4h	154.3k
0		2	107.8u	104.5w	157.7i	155.8j
1			111.3r	107.9u	160.2h	157.2i
2			113.7q	110.1s	163.1g	160.8h
0	8	0	110.8s	107.6u	164.8f	160.9h
1			113.9q	110.8s	166.4e	163.8g
2			114.8p	110.9s	167.9d	164.5f
0		2	114.2p	111.3r	168.8c	164.8f
1			116.7o	114.8p	170.4b	167.4d
2			119.5n	116.1o	171.3a	170.8b

*Data with the similar letters are not significantly different (P=0.05)

Table 6: The effect of iron slag enriched cow manure, zeolite, pumice and wastewater to water ratio on soil Fe concentration (mg/kg soil)

Iron slag (%)	Pumice (%)	Zeolite (%)	Cow manure (t/ha)			
			0		30	
			Wastewater to water ratio		Wastewater to water ratio	
			1:1	2:1	1:1	2:1
0	0	0	36.9t*	34.3v	50.7i	49.8j
1			37.1s	35.2u	53.6g	52.6h
2			38.5r	37.6s	54.8f	53.9g
0		2	38.2r	37.1s	54.1f	50.3i
1			39.9q	38.5r	55.2e	53.1g
2			42.1o	39.8q	56.9d	54.1f
0	8	0	39.3q	38.7r	56.1d	53.5g
1			43.1n	39.5q	57.6c	55.1e
2			45.7l	40.4p	58.3b	56.1d
0		2	43.7n	40.7p	57.8c	55.5e
1			44.9m	42.3o	58.9b	57.7c
2			46.1k	43.1n	59.4a	58.8b

*Data with the similar letters are not significantly different (P=0.05)

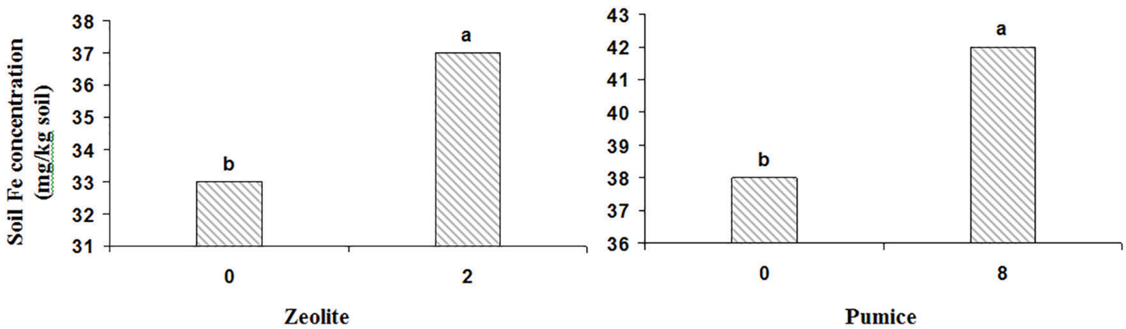

Figure 1: The simple effect of applying zeolite and pumice on soil Fe concentration

effect of applying zeolite and pumice (Figure 1) on decreasing soil Fe concentration was significant.

Using Pb-polluted wastewater caused a marked elevation in superoxide dismutase (SOD) activity (Table 7). Based on the results of this study, a significant increase by 4.1% in the SOD enzyme activity was observed when the plants were irrigated with the battery factory wastewater with a rate of 2:1 (wastewater/water). The plant Pb concentration showed a positive correlation with the SOD enzyme activity. Accordingly, with decreasing the wastewater/water ratio from 2:1 to 1:1, the SOD enzyme activity and plant Pb concentration were decreased. Soil amended with 2 and 8% (W/W) zeolite and pumice caused a significant decrease in the SOD enzyme activity. For

Table 7: The effect of iron slag enriched cow manure, zeolite, pumice and wastewater to water ratio on SOD enzyme activity (U/mg protein)

Iron slag (%)	Pumice (%)	Zeolite (%)	Cow manure (t/ha)			
			0		30	
			Wastewater to water ratio		Wastewater to water ratio	
			1:1	2:1	1:1	2:1
0	0	0	44.1b*	45.4a	42.4d	43.7c
1			42.7d	44.9b	40.6f	41.4e
2			41.6e	43.7c	39.6g	40.2f
0		2	42.8d	43.6c	40.8f	41.5e
1			41.4e	42.6d	39.3g	40.8f
2			40.7f	41.8e	37.2i	39.4g
0	8	0	40.1f	41.8e	35.1k	37.2i
1			38.2h	39.8g	34.1l	35.2k
2			35.1k	36.3j	31.7n	32.2m
0		2	37.1i	38.5h	34.1l	35.8k
1			32.1m	34.3l	30.4o	31.4n
2			28.7q	29.8p	25.6r	28.3q

*Data with the similar letters are not significantly different (P=0.05)

instance, a significant decrease by 6.4 and 8.4% was observed when the soil was amended with 2 and 8% (W/W) zeolite and pumice, respectively. Enrichment of cow manure with iron slag at the rates of 1 and 2% (W/W) had a significant effect on decreasing the SOD enzyme activity. The results of our studies showed that the SOD enzyme activity in the plants grown in the soil amended with 1 and 2 % (W/W) iron slag significantly decreased by 3.9 and 4.4%, respectively.

Discussion

Considering the changes in climatic condition of the country toward the arid and semi-arid regions, reuse of wastewater for agricultural use is essential. However, the negative aspects of wastewater should not be ignored. According to the results of this study, applying zeolite or pumice can help us to treat the battery wastewater and decrease the soil and plant Pb concentration that can be related to the role of these organic amendments on increasing the soil sorption properties. Khodabakhshi et al. conducted a study on the role of Pb elimination from battery industry synthetic wastewater by nano-maghemite and concluded that magnetite nanoparticles had a high adsorption capacity for Pb removal from aqueous solution. However, they indicated that Pb removal efficiency was directly affected by pH and time.[19] The positive role of Iranian natural zeolites in removal of lead ions from aqueous solutions was also dinvestigated by Moazeni et al.[20] The results of their study indicated that the heavy metal type and its concentration had a significant effect on Pb removal efficiency by zeolite.[20] Kim et al. (2013) conducted a esearch on the Pb removal from aqueous solution by a zeolite and concluded that at the lower Pb concentration (100 mg/L), 99.2% of the Pb-pollution was removed from aqueous solution.[21] Based on the results of this study, pumice has also the same properties on Pb removal from battery wastewater. Moradi et al. evaluated the efficiency of pumice powder to Pb removal from the aquatic environment, concluding that applying pumice powder had a significant effect on Pb elimination from aqueous solution. In addition, in that research the contact time of the pumice powder and the pH solution were introduced as important factors in changing the Pb solubility in aqueous solution.[22]

Jonasi et al. investigated the effect of pumice stone powder on Pb removal from aqueous solution and concluded that this product can be utilized in adsorptive removal of Cd(II) and Pb(II) ions from aqueous solutions.[23] It is noteworthy that this study was carried out in aqueous solution and it is necessary to be investigated in heavy metal contaminated soils. Generally, pumice is a highly porous volcanic stone with a micro-porous structure, which gives it a high surface area. Pumice has a large proportion of silica sites, which gives it a negatively charged surface, and it has a large number of open sites, which allows the water and ions to move in and out of the crystal structure. Li et al. also reported that silicate could enhance the plant resistance to the toxicity of heavy metals attributed to the decrease in the soil Pb availability due to the increase in the soil pH.[24] According to the results of their research, the amendment of 800 mg kg^{-1} Si significantly increased the soil pH and decreased exchangeable Pb, thus reducing the soil Pb availability. In addition, they mentioned that the soil amended with Si significantly increased the plant biomass in the Pb-polluted soil.[24]

Based on the results of this study, applying cow manure significantly increased and decreased the plant biomass and plant Pb concentration, respectively, which was related to the role of applying cow manure on increasing the nutrient uptake by plant and thus increasing the plant biomass. In addition, the positive role of applying cow manure on increasing the soil sorption properties and consequently decreasing soil Pb availability cannot be ignored. Mashayekhi et al. investigated the effect of EDTA chelate and cow manure on the cd uptake by pot marigold in polluted soil and reported that applying 25 and 50 t/ha cow manure had a significant effect on decreasing the soil and plant-heavy metal concentration. In addition, they mentioned that applying organic amendment had a positive effect on the plant biomass, thereby increasing the plant root exudate that has a direct effect on soil microbial activity.[25] The positive role of soil microbial activity on immobilizing the heavy metals has been reported by researchers.[26-28] In addition, Hoshyar et al. w also mentioned that the organic and inorganic fractions of organic amendments have a significant effect on heavy metal immobilization in the soil.[29] Generally, trace element adsorption capacity varies with the amount of sportive phase and chemical property of organic amendments. It is noteworthy that oxide mineral surfaces are important to determine the bio-availability of trace elements in organic-treated soils. According to the results of these studies, decreasing plant Pb concentration reduced the SOD enzyme activity that can be attributed to the plant's resistance to heavy metal against oxidative stress. Generally, heavy metals are unable to participate directly in biological redox reactions; it induces oxidative stress via different indirect mechanisms. For example, heavy metals stimulate the activity of NADPH oxidases, resulting in extracellular superoxide, H_2O_2 accumulation and lipid peroxidation and oxidative burst.[30]

On the other hand, the results of this study showed that cow manure enriched with iron slag significantly decreased the negative effect of soil irrigation with Pb-contaminated wastewater that might be related to the interaction effect of Fe and heavy metals. Iron slag is a by-product of Mobarakeh Steel Complex and more than 85% of its composition is iron oxide in two and trivalent forms. Generally, iron in arid and semi-arid regions is trivalent which makes it unavailable for plant uptake, especially in soils with low organic matter, and increasing soil organic matter can help to increase the soil nutrient availability. Therefore, enrichment of cow manure with iron slag can be a useful method for increasing the soil and plant iron availability and consequently decrease the heavy metal uptake by plants. However, the role of applying cow manure on increasing soil cation exchange capacity which helps to reduce the adverse effect of soil irrigation with wastewater cannot be ignored. The interaction effect of heavy metals and Fe has been mentioned by researchers.[31, 32] Alidadi Khaliliha et al. investigated the interaction effect of Fe and Pb on the plant growth and elements uptake in Cress (*Lepidium sativum* L.) and concluded that Fe plays an important role in reducing the adverse effects of Pb in the cress.[33] The study of Nazar et al. also showed that plant nutrient elements can lead to alleviating Cd stress in the crop plants that is similar to our research.[34] Tafvizi et al. also investigated the effect of Pb sources on Fe, Mn, and Zn concentrations in different varieties of maize and concluded that soil pollution with pb could decrease the nutrient uptake by plants.[35] Accordingly, using organic amendments such as zeolite or pumice can decrease the negative effect of applying Pb-polluted wastewater, thereby increasing the essential element such as Fe by plants.

Conclusion

Application of iron enriched cow manure had a significant effect on decreasing the soil and plant Pb concentration that might be related to the role of nutrient elements (such as Fe) in decreasing the heavy metal availability (interaction effects). Increasing soil and plant Fe concentration due to applying iron enriched cow manure confirms our results clearly. On the other hand, adding 2 and 8% (W/W) zeolite and pumice had a significant effect on decreasing the soil and plant heavy metal availability that can be attributed to the role of these organic amendments on increasing soil sorption properties, thereby decreasing soil and plant heavy metal availability. Plant irrigation with wastewater of battery factory significantly increased the plant Pb concentration. However, applying zeolite and pumice can contribute to wastewater treatment. Among this, mixing well water with wastewater in proportion 1:1 compared to 2:1 (wastewater/water) significantly decreased the Pb concentration by sunflower. However, the plant type and soil properties play an important role in the amount of Pb uptake by plants that should be considered in the future studies.

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Conflict of Interest: None declared.

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