EFFECT OF IRRIGATION BY WASTE WATER ON ACCUMULATION OF HEAVY METALS IN SOIL AND PLANT

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Abstract:

A pot experiment was carried out to determine the effect of using waste water irrigation on the concentrations of (Pb, Cd, Cu and Zn) in soil and their subsequent accumulation in plant. Waste water was diluted to give four treatments: T1 (waste water), T2 (1:1), T3 (2:1) well water: waste water and T4 (well water) as control. Higher concentrations of Pb, Cd, Cu and Zn were observed in soil of T1 compared toT4. Pb and Cd in (tops and roots) of chard were above the maximum permissible level in vegetables (WHO,1984). The results also showed a decrease in microbial density caused by high level of heavy metals concentration and an increase in aggregate stability.

Keywords: *waste water, heavy metals, soil, physio-chemical properties.*

Introduction:

There are gradual declines in availability of fresh water to be used for irrigation. This scarcity forces farmers to consider any source of water which is easily available and cheap. So they are attracted to use waste water. It has been reported that waste water contains major essential plant nutrients and heavy metals (Singh,et al. 2004). An improvement in the fertility status of the soil but with buildup of heavy metals in the soil when waste water used for irrigation have been reported by Malla, et al. 2007. Continuous usage of waste water for irrigation may result in the accumulation of heavy metals to level above the permissible limits for both animal and human health (Masona, et al 2011). This could also have long term implications for the biological, chemical and physical properties of agricultural soil (Nicholson, et al.2003). When some stress factors are imposed on natural environment, soil, biota can be affected as well as the ecological processing regulating these micro organisms (Olivaral and Pampulha,2006). Various toxic elements in waste water are known to affect soil microbial populations and their associated activities (McGrath, 1994. and McGrath,et al.1995).

Whenever heavy metals are accumulated in the soil, they may transfer to food chain and cause dangerous health effects (Kashif,et al. 2006). Plants grown on the soil polluted with sewage water were found to record higher uptake of heavy metals when compared to plants grown on normal soils (Adhikari,et al. 2004). Vegetables are known to be good absorber of heavy metals from soil (Haiyan and Stuanes, 2003, and Nwajei, 2009, especially those of leafy vegetables because of the fact that they absorb these metals through their leaves (Al-Jassir, et al. 2005). Leafy vegetable, such as spinach appeared to be the highest metal accumulating plant on the bases of overall metal uptake compared to onion and coriander (Sharma, and Shukla, 2013). Farmers are used to grow vegetables for their own consumption and for supply markets in farms where untreated waste water is the main irrigation source, especially in summer season. Therefore, the aim of this research was to evaluate the impact of use of waste water irrigation on some soil physio-chemical and biological properties, especially the concentration of some heavy metals in soil and in different parts of plants and the risk of consuming leafy vegetables grown in field where the farmers use waste water for irrigation purposes.

Materials and methods:

A study was carried out inthe greenhouse of Agriculture College Duhok University in 2013. Soil samples were collected from the surface layer (0-30 cm) of two different textured sites. Table (1) and (2) show some characteristics of these two soils and waste water used.

Table(1): Some selected physical and physiochemical properties of the study soils.

Type of test	Propriety		Unit	Average value	
				Site 1	Site 2
Physical	Particle size distribution	Sand	g kg^{-1}	84	354
		Silt	g kg^{-1}	415	380
		Clay	g kg^{-1}	501	266
		Textural name		Silty clay	Clay loam
Physiochemical	pH			7.43	7.6
	EC		dSm^{-1}	0.397	3.945
	Soluble ions	Ca^{+2}	mmole L^{-1}	1.4	43.2
		Mg^{+2}	mmole L^{-1}	0.45	39.6
		Na^{+}	mmole L^{-1}	0.913	0.127
		HCO_3	mmole L^{-1}	2.4	0.08
	$CaCO_3$		gKg^{-1}	224.5	207.2

Table (2): Some characteristics of the waste water used.

properties		Water Type			
		T_1	T_2	T_3	T_4
pH		8.14	7.88	7.6	7.55
EC (μsm^{-1})		727	754	817	918
HCO^{-}_3	$\mu eq.L^{-1}$	3.0	4.2	4.4	4.2
Cl^{-1}		20	18	21	8.0
Ca^{2+}		1.2	1.4	2.2	2.6
Mg^{2+}		2.6	2.2	1.8	1.6
Fe^{2+}	$\mu g.ml^{-1}$	0.901	*	*	*
Zn^{2+}		0.709	*	*	*
Cu^{2+}		1.401	*	*	*
Pb^{2+}		1.942	*	*	*
Cd^{2+}		0.213	*	*	*

Soil samples were air dried; ground to pass through 4-mm sieve and 5kg was used to fill each pot. The experiment design was factorial CRD. Four Chard seeds were planted in each pot on 1/11/2013 then thinned to one plant per pot on 2/12/2013.

To determine the heavy metal contamination in waste water irrigated plant and soils, the waste water used for irrigation was collected from selected site located near waste water canalin a farmer field where the waste water is directly used for agriculture purpose. The selected field was located in Media district adjacent to (Metran Street) / Duhok governorate**.** The experiment consisted of four water treatments including control, T1 (waste water), T2 (1:1). T3 (2:1) Well water : waste water (v/v) ratios and T4 well water as control, the pots were irrigated with 250 ml (calculated on weight basis) of each water type every 2-3 days.

Pots plant sampling was done on 21/2/2014 and chard plants were also collected randomly from the same field commonly irrigated with waste water. Plants were cut from the surface of the soil and separated to tops and roots. The plant parts were washed, air dried, then dried at 60C^{o} in electric oven weighed, ground and digested in mixture of HNO_3: $HClO_4$ (2:1). Heavy metal in chard tops and roots were analyzed separately.

Pots soils and field soil samples (collected from the top layer 0-30cm) were air-dried and ground to pass through 2-mm sieve for analysis. For heavy metal analysis, the soil samples were extracted with 0.005N DTPA and metals in extract were determined by AAS.

Other properties analyzed include aggregate stability using the wet sieving on samples of aggregates 4-8 mm in size using a nest of 5 sieves: 4, 2, 1, 0.5 and 0.25 mm. The mean weight diameter was determined after shaking for 10 minutes using a vibrating sieving machine. The total numbers of culturable biota was also determined by serial dilution and plating on selective media. The plates were incubated with 1 ml of soil suspensions and cultured at 25-30 C^{o} for 4-7 days.

All the following measurements were made in triplicates.Statistical analysis of the results was done and the differences between means were achieved according to Duncan multiple range test by sing SAS 9.0 program.

Results and discussion:

The results presented in Fig.1 revealed that the soil from the (S2) gave a higher shoots weight compared to (S1) soil and the increase was significant at $P<0.05$. The mean values of tops dry weight corresponding to S2 ranged between 6.876-13.47 g, while it ranged between 3.42-6.40g for S1, however, the highest mean top dry weight obtained from field plants (13.87g).

Regarding the dry weight of roots, data showed that dry weight of roots of S2 were significantly lower compared to those of S1 and field plants (4.891g). The differences in tops and roots dry weight between the two soils could be attributed to the differences in texture, aggregate stability and microbial groups.

In general, data concerning the differences between treatments showed that T1 and T2 gave the highest values and T4 gave the lowest for both tops and roots dry weight. It has been reported that sewage from municipal origin contains major essential plant nutrients and heavy metals (Singh, et al. 2004) that can improve plant growth.

More or less similar pattern of distribution of Cd and Cu concentrations in the two soils were observed Fig.2. In general values for S2 were higher. The concentrations of Cd and Cu of the field soil (0.216 and 1.59 mg kg-1 respectively) were similar to S1 and S2. Our results for Cd and Cu agreed with those obtained by (Rattan, et al. 2005, Grigalavičienė, et al. 2005,Mojiri and Abdul Aziz 2012 and Lonel, et al. 2013). For both elements in the two soils, T1 gave the highest concentration and T4 gave the lowest. Higher concentrations of heavy metals in sewage irrigated soil than soil irrigated with uncontaminated water were also reported by (Mitra and Gupta,1999 andKhurana, et al. 2004).

A gradual decline in soil Pb concentration was recorded with dilution of waste water for both soils. All values were higher for S1 compared to S2, with exception of T1. Pb concentration in field soil was 1.44 mg kg^{-1}. The results for Pb concentrations were in tune with (Grigalavičienė, et al. 2005 and Jayadev, 2012).

No clear differences were found in concentration of Zn in the two studied soils. The concentrations ranged from 0.22 to 0.38 and from 0.31 to 0.33 mg kg^{-1} for S1 and S2 respectively, while it was 0.46 mg kg^{-1} for field soil. These results agreed with (Mojiri and Abdul Aziz, 2012 and Eneje and Lemoha, 2012.).

For all the selected heavy metals, generally the concentrations were significantly higher in plants (tops and roots) sampled from S1 compared to S2 Fig.3. Concerning treatments, in general a gradual decline in all heavy metals concentration was recorded with dilution of waste water. Highest values were found with T1 and T2, and the lowest with T4. The concentration of heavy metals in plants depends on application rate, soil reactions and plant species (Zoubi,et al. 2008). Increased level of sewage water increased the uptake of heavy metals including Cd in crops (Chitdeshwari,et al. 2002). The rate of heavy metals concentration for tops followed the order: Zn > Pb > Cu > Cd while it was Cu > Zn > Pb > Cd for roots. The mean concentrations of heavy metals in plants agreed with the ranges reported by (Lonel,et al. 2013 , Muhammed,et al.2011 and Sulaivany and Al- Mezori, 2007) for Pb and Cd, by (Sulaivany and Al- Mezori, 2007 and Kibria,et al.2012) for Cu and by (Mojiri and Abdul Aziz 2012) for Zn.

The concentrations of heavy metals in soil did not exceed the maximum permissible levels of heavy metals in agricultural soils specific for different countries as shown in tables (3 and 4). The concentrations of Pb and Cd in tops and roots were above the corresponding values of maximum permissible level (MPL) of 0.3 and 0.1 mg kg^{-1} dry weight for Pb and Cd respectively in vegetables as stated by (FAO/WHO,1984.). As we know, Cd and Pb were non-essential elements; they were likely to be a health hazard to human consumers. They may further lead to toxicity not only to plant and animals but also to consumers through the food chain (FAO/WHO, 2011). Cu concentrations in roots also exceeded the (MPL) level recommended by (WHO).

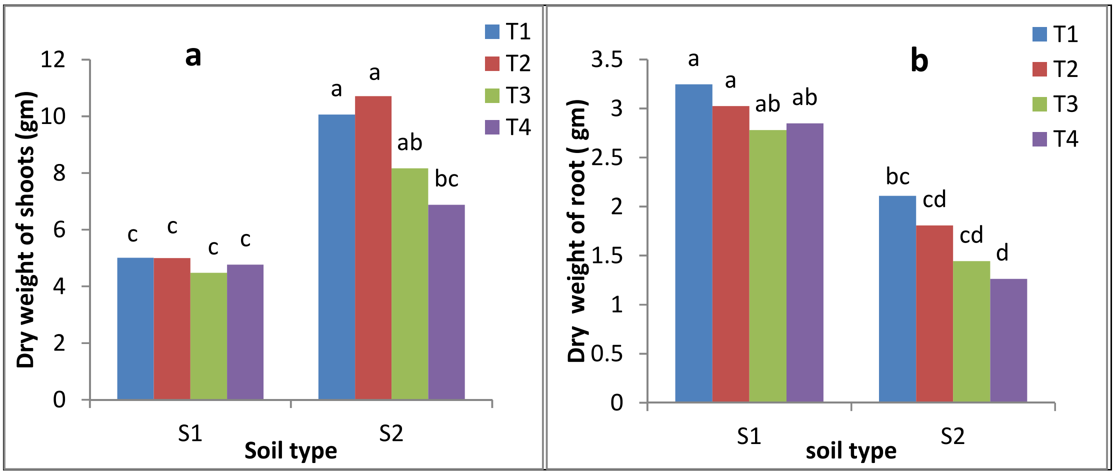
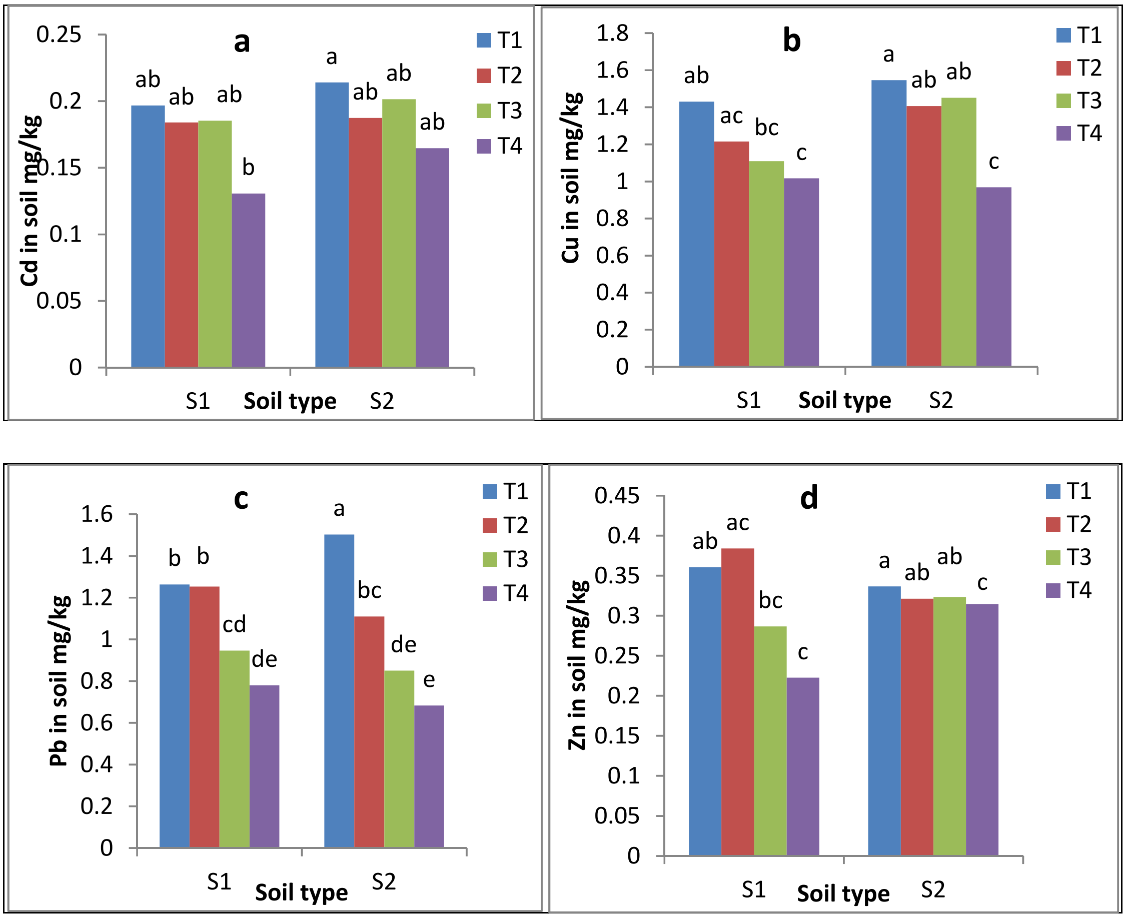


Figure 1: Dry weight of (a) shoots and (b) roots (g)- as influenced by different types of water in the study soils.



Figur 2: Acumulation of heavy metals ($mg.kg^{-1}$)- (a) Cd, (b) Cu, (c) Pb and (d) Zn in the selected soils.

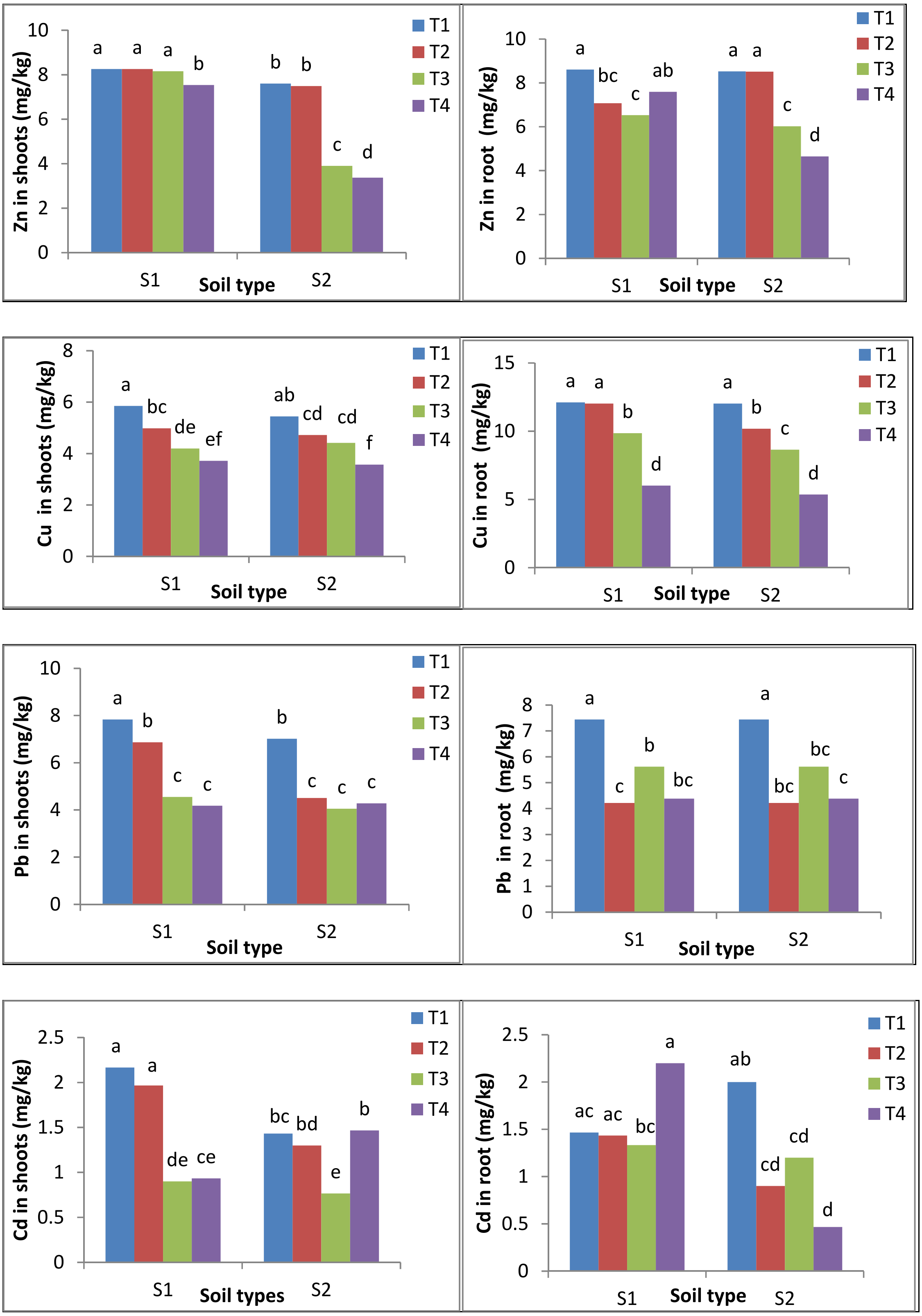


Figure 3: Heavy metals concentration in shoots and roots.

Table (3): Range of heavy metals concentration in the study soils.

Soil type	Range of heavy metals concentration (mg kg^{-1})			
	Pb	Cd	Cu	Zn
S1	6.9 – 14.4	0.08 -0.26	0.74 -1.92	0.20 – 0.44
S2	6.3 – 17.3	0.16 -0.24	0.90 -1.56	0.28 – 0.64

Table(4): Maximum permissible levels of heavy metals in agricultural soils from different countries.

Country	Maximum permissible concentration (mg kg^{-1})			
	Pb	Cd	Cu	Zn
Germany 1991(1)	100	1.5	60	-
Spain 1990 (1)	50	1.0	50	-
Denmark 1989 (1)	40	0.5	40	-
France 1988 (1)	100	2.0	1000	-
E.C.R. (2)	50	1.5	60	-
Russia (3)	30	2.0	50	-
FAO (4)	100	3.0	100	300
FAO (5)	85	0.8	36	-

According to: 1)McGrath1993, 2)Wild 1992, 3)Bespamiatnov1985,4)Lonel,et al.2013, 5)McGrath 1994

The results of microbial populations are shown in table (5). The decrease in microbial density may caused by high level of heavy metals contamination. The count show a marked decrease in total culturable numbers of microbial groups for T1 in both soils compared to control T4. The changes in soil conditions due to heavy metals contamination have a large negative effect on soil microbes (Oliveira1 and Pampulha 2006). This effect was attributed by (Kandeler,et al. 1996 and Brookes and McGrath,1984) to the toxic metals present in waste water and sluge on soil microbes and may therefore result in crop contamination (Hanjraa, et al.2012). The results were similar to that reported by (Šmejkalová,et al.2003).

Water aggregate stability decreased with dilution of waste water table (5). Many studies have investigated various soil physical and chemical properties in the area irrigated with wastewater. Among the potential risks associated with irrigation with treated wastewater are degradation of aggregate stability, resulting decrease in soil hydraulic conductivity and compaction decrease in soil aeration increase in runoff and finally increasing soil erosion (Tarchitzky and Golobati, 1999). Opposite finding have been reported concerning the effects of dissolved organic matter on the soil structural stability. It was suggested that organic substances have been considered as cementing agents that improve aggregate stability (Goldberg, et al. 1988).

Table(5): Total count of bacteria ($x10^{-4}$) and water aggregate stability (%)

	Total count bacteria $x(10^{-4})$		Water Aggregate Stability (%) for aggregates 4-8mm	
	S1	S2	S1	S2
T1	371	171	3.354	2.485
T2	361	294	3.291	2.284
T3	388	330	3.050	1.560
T4	456	362	2.391	1.795
Field	391			

Conclusions:

This study has shown that accumulation of heavy metals (Pb, Cd, Cu and Zn) in waste water led to accumulation in soil and finally in plant. This contamination comes from maniples effluent discharges which invariably find their usage into agricultural crops. Further detailed research is required for more accurate evaluation of heavy metals accumulation in soil and different plants. Steps should be taken to control the heavy metals pollution.

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کارتێکرنا ئاڤدانا ب ئاڤا سولینا ل سەر کومکرنا توخمێت گران د ئاخێ و رووەکی دا

پوختە:

ڤەکولین هاتە ئەنجامدان دناف قافکادا بو خاندنا کارتێکرنا ئاڤدانێ ب ئاڤا سولینا ل سەر خە ستییێت Pb, Cd, Cu, Zn دناف ئاخ و رووەکی دا. خە ستیا ئاڤا سولینا هاتە کیمکرن کو پێك دهێت ب چار مامەلا: T1 (ئاڤا سولینا)، T2 (1:1)، و T3 (2:1) ئاڤا بیرێ: ئاڤا سولینا و T4 ئاڤا بیرێ وەك مامەلا بەراورد. ئەنجامێت ڤێ ڤەکولینێ دیاربوون کو خەستیا هەر ئێك ژ Pb, Cd, Cu, Zn دئاخا مامەلا T1 بەراورد دگەل مامەلا T4. خەستیا هەر ئیك ژ Pb و Cd د پارچا سەری و رەگێت رووەکی دا بلندتربوو ژ خەستیا رێپێدای و زەرزەواتی ل دویف رێکخراوا (WHO, 1984). هە روەسا ئەنجاما وەسا دیارکر کو هژمارا هویرەزیندەوەرا یا کیم بووی ژبەر خەستییێت بلندییێت توخمێت گران و زیدەبوونا خوراگریا گرگتێن ئاخێ.

تاثير الري بمياه المجاري على تراكم العناصر الثقيله في التربه والنبات

الخلاصه:

اجريت تجربة في سنادين لدراسة تاثير الري بمياه المجاري على تراكيز Pb, Cd, Cu, Zn في التربه والنبات. تم تخفيف مياه المجاري لتشمل اربعة معاملات:T1 (مياه مجاري)، T2(1:1)،وT3 (2:1) ماء بئر:ماء مجاري وT4 مياه بئر كمعاملة مقارنه. اظهرت النتائج زياده تراكيز كل من Pb, Cd ,Cu, Zn في ترية معاملة T1 مقارنة بمعاملةT4 . كانت تراكيز كل من Pb وCd في (الجزء العلوي والجذور) للنبات اعلى من التراكيز المسموح بها للخضروات حسب (WHO, 1984). كمااظهرت النتائج انخفاض في عدد الاحياء المجهريه بسبب التراكيز العاليه للعناصر الثقيله وإزدياد في ثباتية التجمعات.