DETERMINING OF HEAVY METALS CONTENT IN THREE LEAFY VEGETABLES TREATED WITH COMPOST PRODUCED BY QUASHIE MUNICIPAL SOLID WASTE PLANT

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1.ABSTRACT

Due to prior analysis of compost produced at the Quashie waste facility, which disclosed increased levels in heavy metals (specifically lead, cadmium, copper, nickel, chromium, cobalt and zinc); this study tested vegetables grown using the same compost for these same metals in three leafy vegetables (Arugula, Celery and Chard). The results showed various responses of the plants to the treatments in terms of all studied variables. For most variables, plant applied with animal manure were superior to those that treated with compost; yet, they were not significantly different from those that applied by six and nine litters of compost. The heavy metals content of all samples was in accordance to the European Food Law, except for chromium, which showed to be toxic in one celery sample (0,53 mg.kg^{-1})., and cannot be used for human consumption. Concentrations of heavy metals in control plants were close to those of treated plants with compost showing a possible contamination from different source. This test ensures appropriate use of the compost and prevents the use of potentially harmful compost in the future.

KEYWORDS: Compost, Heavy metals, Leafy vegetables, Animal manure.

2. INTRODUCTION

The solid waste is increasing with the population growth; therefore, a proper management of this type of waste has become crucial (Çalışkan, Barışçı *et al*. 2014). Quashie waste facility is the largest facility for waste management in Duhok governorate, Kurdistan of Iraq and in whole Iraq. The facility was built in a good standard; one of the products that separated from the waste is the organic matters that is converted to compost, and then can be reused for plants.

In order to provide good quality compost, the facility is assessing the product periodically. The assessments are conducted by the facility, governmental institutions, University of Duhok and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). Because the organic waste is not separated from the other waste, the facility, with GIZ cooperation, has decided to analyze a number of samples for heavy metals content according to European standards (Table 1).

Both samples were collected in December 2013 and in March 2017 showed concentrations above the limit according the German Bio-Waste-Regulation. It is understandable that the values of the samples from “fresh compost” are higher than the values of the samples from “old compost”, because the old compost has less organic matter and therefore the heavy metals are distributed in less dry matter. At the end, the amounts of heavy metals distributed on the soil by fresh or old compost are about the same, because of the same materials, used for composting. This is because heavy metals will not evaporate or degrade during the compost process under normal temperature conditions (Christian Letalik, personal communications, 2017).

Table (1) shows increased levels of heavy metals in the compost specifically lead, cadmium, copper and zinc. However, previous studies on heavy metals behavior in different soils showed limited movement of heavy metals in alkaline and clay soils (McLean, Bledsoe *et al*. 1992). Therefore, it is important to know whether the

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concentration of heavy metals inside plant tissues is accordance to the European standards or not.

Studies showed significant differences in corn production when applied by animal manure compared to those that applied by compost (Eghball, Ginting *et al*. 2004). On the other hand, a study about heavy metals accumulation in Radish plant showed that the heavy metals, particularly Zn, are accumulating in leaves more than other parts of the plant (Abdel and Ibrahim 2018). Thus, it is important to study the variation in leafy plants production using both animal manure and compost. This will help the decision makers to choose the right fertilizers according to the results, after comparing the price and other factors of each of them.

This study examines the concentrations of heavy metals in three leafy vegetables (arugula, celery and chard). Particularly, it tests the hypotheses that: (i) The concentration of the six heavy metals in three leafy vegetables is low and variable; (ii) There is no contamination from air pollution; and (iii) The Plants will respond to animal manure more than the compost in terms of growth and the studied variables.

Table (1): Heavy metal concentrations of compost samples from Quashie (March 2017 and December 2013).

	Heavy metals in compost of Quashie compost, limits for Europe					
Heavy metals	Fresh compost (not completely decomposed), March 17	Old compost (completely decomposed), March 17	Limits	December 13	Limits	Limits
	Quashie	Quashie	BKG BRD*	Quashie	Italian	Spain
	mg.kg^{-1} dm	mg.kg^{-1} dm	mg.kg^{-1} dm	mg.kg^{-1}dm	mg.kg^{-1}dm	mg.kg^{-1}dm
Thallium Tl	< 0.1	< 0.1	-	-	-	-
Arsenic As	1.4	2.1	-	-	-	-
Lead Pb	129	214**	150	99.6	140	1.200
Cadmium Cd	3.77**	6.64**	1.5	2.31**	1.5	40
Chromium Cr	30.5	37.2	100	25.5	100	750
Nickel Ni	34.8	42.8	50	36.1	50	400
Mercury Hg	0.51	0.68	1	0.3	1.5	25
Copper Cu	221**	298**	100	126**	300	1.750
Zinc Zn	505**	680**	400	340	500	4.000

* Federal Compost Law Germany, ** above limits, dm dry matter.

3. METHODOLOGY

This study was conducted in the field at the University of Duhok (UOD), Kurdistan region-Iraq. The experimental units were distributed randomly using RCBD design. Three concentrations of compost (3 l.(m^2)$^{-1}$ (C3), 6 l.(m^2)$^{-1}$ (C6) and 9 l.(m^2)$^{-1}$ (C9)); and animal manure (AM) (six litters.(m^2)$^{-1}$) were compared to control using ANOVA and Duncan’s multiple test. While the recommended amount of compost is between 4 and 10 liters per m² in Germany (Christian Letalik, personal communications, 2017), Iraqi soil does not require quite as much compost, which brought us to decide to use the compost concentrations of 3, 6, and 9 liters per m² respectively, providing scientifically valid, equal additions of soil in each treatment. The plots (0.5 m^2) were distributed randomly within each block. A study about heavy metals accumulation in Radish plant showed that the heavy metals, particularly Zn, are accumulating in leaves more than other parts of the plant (Abdel and Ibrahim 2018). Therefore, three leafy vegetables (Chard, Arugula and Celery) were planted with three replications for each of them. The seeds were sown on 14/9/2017 at a rate of Celery 4.2 gm^{-1}, arugula 4.2gm^{-1} and chard 4.4 gm^{-1} then the extra plants were thinned (pulled out) to have more space. Drip irrigation system was used for water supply. To accelerate the germination, the plots were covered by a sheet of polyethylene. A number of morphological traits were measured between 23 to 26 of October 2017. Those morphological traits included, plant height (cm), leaf width (cm), leaf length (cm), petiole thickness (mm), fresh weight and dry weight (g). In addition, leaf area (cm^2) was measured using a smartphone application (petiole, Version 0.7 by Petiole LTD, http://petioleapp.com, 2017). Six leaves within each plot were selected randomly, and their means were calculated to represent the leaf area. The samples were oven dried according to (Brower, Zar *et al*. 1998; Godbold and Hüttermann 1988; and Teramura, Perry *et al*. 1984), and the concentration of heavy metals was measured at Hohenheim University, Germany. In Germany, the samples were digested according to (VDLUFA, 2011a) by microwave heated digestion with the MLS Ultraclave III and then measured by the Perkin Elmer ICP-MS NexION 300X (VDLUFA, 2011b). Approximately 0.2 to 0.3 g of each sample was measured for digestion process. One mL of H_2O and then 2.5 mL of HNO_3 were applied to the samples. After digestion, H_2O was added to the solutions until they became 10 mL. The mean of the three replications were extracted to represent the value of certain heavy metal content.

4. RESULTS AND DISCUSSION

4.1. Morphological Traits

The results showed various responses of the plants to the treatments in terms of all studied variables (Tables 2, 3, 4 and 5). Arugula plant with AM, C3, C6 and C9 were significantly higher than control plants. On the other hand, celery plants were significantly longer when they treated with AM and C3; however, celery plants treated with C6 and C9 were not significantly longer than those of control. Contrarily, chard plants were significantly longer in AM, C6 and C9 treatments than those plants in C3 and control treatments. Yet, overall, AM produced superior plants in terms of plant height, although plants treated with all concentration of compost gave significantly higher plants than those in control (Table 2).

Wider leaves were produced when plants were treated with AM, C3, C6 and C9 (Table 2). Although arugula and chard plants produced wider leaves when they applied by AM, their leaves were not significantly wider than those plants applied with all concentrations of compost. Whereas the results showed no significant differences in leaf width of celery plants within all plots (Table 2).

Table (2): The effect of AM and three concentrations of compost compared to control on plant height and leaf width of arugula, celery and chard.

	Plant height (cm)				Leaf Width (cm)			
Treatments	**Plants**				**Plants**			
	Arugula	**Celery**	**Chard**	**Mean of Treatments**	**Arugula**	**Celery**	**Chard**	**Mean of Treatments**
AM	35.67 bc	20.35 e	46.53 a	**34.18 a**	9.83 c	3.84 e	14.67 a	**9.45 a**
C3	34.07 bc	19.17 e	36.48 bc	**29.9 b**	8.03 cd	3.51 e	14.22 ab	**8.59 a**
C6	34.2 bc	15.32 f	43.58 a	**31.03 b**	8.63 cd	2.99 e	14.39 ab	**8.67 a**
C9	33.03 c	14.14 f	43.83 a	**30.33 b**	8.77 cd	3.11 e	14.4 ab	**8.76 a**
Control	28.97 d	13.31 f	37.44 b	**26.57 c**	6.9 d	2.48 e	12.35 b	**7.24 b**

Different letters within each comparison represent significant differences according to Duncan´s multiple range test at 5% level.

Longer leaves and thicker petioles were found when plants were treated with AM, C6 and C9 (Table 3). Arugula and chard gave longer leaves and thicker petiole when AM, C6 and C9 were applied, except for chard leaf length when applied by C9. Interestingly, the length of leaves and the petioles thickness of celery plants found to be significantly the same in all treatments (Table 3).

Table (3): The effect of AM and three concentrations of compost compared to control on leaf length and petiole thickness of arugula, celery and chard.

Treatments	Leaf length (cm)				Petiole Thickness (mm)			
	Plants				Plants			
	Arugula	Celery	Chard	Mean of Treatments	Arugula	Celery	Chard	Mean of Treatments
AM	19.47 cd	3.06 g	30.26 a	**17.59 a**	5.657 d	1.847 g	12.727 a	**6.743 a**
C3	15.63 ef	3.05 g	22.2 c	**13.63 b**	4.677 e	1.377 g	9.55 b	**5.201 b**
C6	18.17 de	2.54 g	27.27 ab	**15.99 a**	5.143 de	1.347 g	12.487 a	**6.326 a**
C9	18.07 de	2.58 g	26.69 b	**15.78 a**	5.41 de	1.29 g	12.177 a	**6.292 a**
Control	13.2 f	4.58 g	21.85 c	**13.21 b**	3.317 f	0.937 g	7.947 c	**4.067 c**

Different letters within each comparison represent significant differences according to Duncan´s multiple range test at 5% level.

The statistical findings showed significant differences in fresh weight, but not dry weight, of all plants together as compared to those found in control (Table 4). Regarding single plant type, arugula and celery plants showed no significant differences in fresh and dry weight among treatments. However, the fresh weight of chard was superior when the plants applied by AM and C6. Whereas dry weight of chard plants was superior when plants applied by C6 (Table 4). The leaves of chard are larger than other studied plants; this could affect the results of overall plants together.

Table (4): The effect of AM and three concentrations of compost compared to control on fresh weight and dry weight of arugula, celery and chard.

Treatments	Fresh Weight (g)				Dry Weight (g)			
	Plants				Plants			
	Arugula	Celery	Chard	Mean of Treatments	Arugula	Celery	Chard	Mean of Treatments
AM	32.93 c	1.74 d	88.58 a	**41.08 a**	2.6 d	0.29 f	9.36 ab	**4.083 a**
C3	28.32 c	1.17 d	67.57 b	**32.35 ab**	2.83 d	0.213 f	6.92 c	**3.321 a**
C6	30.71 c	0.95 d	96.04 a	**42.57 a**	2.85 d	0.177 f	10.303 a	**4.443 a**
C9	26.99 c	0.78 d	86.54 a	**38.1 ab**	3.1 d	0.14 ef	8.563 abc	**3.934 a**
Control	21.31 c	0.78 d	65.59 b	**29.23 b**	2.223 de	0.163 ef	7.437 bc	**3.274 a**

Different letters within each comparison represent significant differences according to Duncan´s multiple range test at 5% level.

Interestingly, the leaf area of arugula and celery found to be significantly the same in all treatments; however, leaf area of chard was significantly larger when the plants applied by AM, C6 and C9 (Table 5). This, again, could be the reason behind the significant differences among treatments when all plants measured together.

Celery germinated later than other two tested plants. In addition, continues irrigation caused washing off for the nutrients far from their shallow roots. Those two reasons could be the key of not showing response to AM and compost.

Table (5): The effect of AM and three concentrations of compost compared to control on leaf area (cm^2) of arugula, celery and chard.

Treatments	Plants			
	Arugula	**Celery**	**Chard**	**Mean of Treatments**
AM	124.1 c	20.3 d	333.7 a	**159.4 a**
C3	109.3 c	12.3 d	237 b	**119.5 bc**
C6	111.8 c	9.4 d	320.4 a	**147.2 ab**
C9	117.3 c	8.8 d	318.7 a	**148.3 ab**
Control	85.7 c	8 d	189.6 b	**94.5 c**

Different letters within each comparison represent significant differences according to Duncan´s multiple range test at 5% level.

4.2. The Concentration Of Heavy Metals

The results supported the first hypothesis that the concentration of the six heavy metals in three leafy vegetables is low and variable, except chromium, which was quit high in one celery sample. Although there are some differences between the triple determinations for some elements, the results calculated on the fresh material before drying are more similar because they are smaller. It is enough for the evaluation of the samples. Comparing the results to European food law and other literature will be discussed in details. The concentrations of the six heavy metals in both dry and fresh weights for arugula, celery and chard are shown in Table (6).

4.2.1. Copper Cadmium and Lead

For copper (Cu), compared to this limits, calculated on the fresh material, given in the COMMISSION (2008) and No (2005): arugula: 100 $mg.kg^{-1}$; chard: 20 $mg.kg^{-1}$; celery leaves: 50 $mg.kg^{-1}$; celery: 20 $mg.kg^{-1}$, the samples are in accordance with the European food law. For Cadmium (Cd) compared to the limits calculated on the fresh material given in the REGULATION (2014) and VO (EG) (1881/2006), leafy vegetables, celery leaves and celery: 0,20 $mg.kg^{-1}$; the samples are also in accordance with the European food law. Same thing was shown in the results for lead (Pb) (COMMISSION 2015; and COMMISSION (2006): Leafy vegetables: 0,30 $mg.kg^{-1}$.

4.2.2. Nickle (Ni):

According to the European Food Safety Authority (EFSA), the Tolerable Daily Intake (TDI) for nickel is 2,8 $mg.kg^{-1}$body weight. If we have a person of 60 kg Body weight; therefore, the tolerable daily intake would be 168 µg. The sample with the highest amount of Ni was one replication of the C3 celery (0,782 $mg.kg^{-1}$). This mean that the Person can have about 215g of this celery sample to be in accordance of the TDI of Ni.

4.2.3. Zinc (Zn):

According to the literature (Frede, W. ed., 2006), the Provisional Maximum Tolerable Daily Intake (PMTDI) for zinc is 1 $mg.kg^{-1}$ body weight. A sixty kg Person could have a daily intake of 60 mg Zn. The sample with the highest amount of Zn was the third replication of C3 celery (5,04 $mg.kg^{-1}$). This means that a person can have about 11,9 kg of this celery sample in his meal to be in accordance of the PMTDI of Zn.

4.2.4. Chromium (Cr):

Only the total amount of Cr has been analyzed in this study. The amount of Cr in other foods is much higher, e.g. quince: 17 $mg.kg^{-1}$, Rice: 6,8 $mg.kg^{-1}$, brazil nuts: 1 $mg.kg^{-1}$. The sample with the highest amount of Cr was the third replication of C3 celery (0,53 $mg.kg^{-1}$). Chromium (VI) compounds shown to be toxic and can not be used for human consumption.

4.2.5. Cobalt (Co):

According to Belitz, H.D., Grosch, W. and Schieberle, P. (2008), the daily intake of cobalt is between 5-200 µg. Compared to other foods (e.g. chocolate: 0,312 $mg.kg^{-1}$, cocoa powder: 1,013 $mg.kg^{-1}$), the amounts of Co in the samples are low.

Table (6): The concentration of six heavy metals in both dry weight and fresh weight of arugula, celery and chard. The mean of three replications was subtracted for each treatment.

Sample name	Results (dry matter)							TS %	Results (fresh samples)						
	Cd ICP-MS mg/kg	**Cr ICP-MS mg/kg**	**Co ICP-MS mg/kg**	**Cu ICP-MS mg/kg**	**Ni ICP-MS mg/kg**	**Pb ICP-MS mg/kg**	**Zn ICP-MS mg/kg**		**Cd ICP-MS mg/kg**	**Cr ICP-MS mg/kg**	**Co ICP-MS mg/kg**	**Cu ICP-MS mg/kg**	**Ni ICP-MS mg/kg**	**Pb ICP-MS mg/kg**	**Zn ICP-MS mg/kg**
C3 Arugula	0.996	2.451	0.348	5.347	2.543	0.303	21.771	9.979	0.099	0.246	0.035	0.533	0.255	0.030	2.848
C3 Celery	0.183	4.441	0.581	9.181	6.473	0.692	46.953	10.200	0.019	0.451	0.059	0.940	0.657	0.070	3.615
C3 Chard	0.159	1.483	0.441	6.697	1.393	0.212	20.291	18.635	0.030	0.278	0.082	1.241	0.260	0.040	2.088
C6 Arugula	1.015	1.830	0.247	5.106	1.962	0.228	21.267	9.253	0.094	0.168	0.023	0.474	0.181	0.021	2.782
C6 Celery	0.122	3.441	0.459	7.994	5.211	0.569	35.125	10.761	0.013	0.370	0.049	0.860	0.560	0.061	2.705
C6 Chard	0.206	1.746	0.553	7.879	1.795	0.230	22.352	18.598	0.038	0.327	0.103	1.460	0.337	0.043	2.300
C9 Arugula	1.020	1.698	0.242	5.362	1.923	0.224	21.781	11.544	0.118	0.198	0.028	0.615	0.223	0.026	2.849
C9 Celery	0.131	3.079	0.409	8.566	4.477	0.956	41.009	9.835	0.013	0.304	0.040	0.847	0.443	0.096	3.158
C9 Chard	0.190	1.588	0.476	7.706	1.607	0.209	24.241	17.361	0.032	0.276	0.083	1.343	0.279	0.037	2.494
Control Arugula	1.222	2.008	0.265	5.476	2.180	0.238	22.207	10.448	0.128	0.209	0.028	0.574	0.227	0.025	2.905
Control Celery	0.162	3.494	0.456	7.705	5.668	0.505	37.592	11.277	0.018	0.394	0.052	0.868	0.639	0.057	2.895
Control Chard	0.173	1.787	0.515	7.292	1.751	0.220	21.427	20.884	0.036	0.376	0.108	1.524	0.367	0.046	2.205

Heavy metals movement and adsorption in the soil is influenced by many factors such as clay contents, soil pH and others (McLean, Bledsoe *et al*. 1992). McLean, Bledsoe *et al*. (1992) found that Cd and Pb are less soluble in those soils with high pH and clay contents, like almost all soils in Duhok. This is because Cd and Pb can be changed into other compounds by binding with carbon, oxygen and phosphorus that are more stable (McLean, Bledsoe *et al*. 1992). In addition, McLean, Bledsoe *et al*. (1992) addressed that clay soils can trap Zn rapidly in there particles. Accordingly, this could be the reason of having low amounts of heavy metals in the analyzed samples.

Interestingly, the results did not supported the second hypothesis that there is no contamination of heavy metals from air pollution (Table 6). The untreated plant by compost showed very close ratio of heavy metals to those plants that were treated by compost with different concentration (Table 6). A number of studies showed that there is a risk of possible contamination by heavy metals to the areas near the highways (Ferguson and Kim, 1991; De Miquel *et al*., 1997; Naqerotte and Day, 1998; Sezgin, Ozcan *et al*. 2004). The study location was about 150 m away from the highway. In addition, the quality of fuel that is used by most of cars in Duhok is poor due to its lower price. This could be the reason of having such concentrations of heavy metals in control plants. Sezgin, Ozcan *et al*. (2004) found toxic heavy metals, particularly Zn, above the limit even about 500m away from highways.

It can be concluded that the quality of compost in terms of production is competing the animal manure. In addition, the concentrations of the six heavy metals that were tested in this study are in accordance to the European standards. Although the previous samples of compost showed high concentrations of heavy metals, it did not necessarily means that they can be accumulated in the plant tissues. Furthermore, the existence of heavy metals in control plants showed the possibility of contamination by heavy metals from different source other than the compost. Accordingly, further studies are required to examine the contamination of soil, and air and plants close to the highways. Thus the compost can be used for vegetable production, but a number of recommendations must be taken into account.

During the study period, several important points have been noticed that can be changed for better quality compost. Firstly, the solid waste is collected all together from the sources; therefore, it can be recommended to separate the waste bins according to the type of the waste. This will prevent the heavy metals to contaminate the organic waste. Secondly, from the observations, there was a high amount of broken glasses in the compost. It can be solved by both separating the waste bins from the source and adjusting the machines in the facility to prevent passing the glasses. Thirdly, the compost was not decomposed properly. In addition, there was a high amount of sunflower’s seed peels. Those peels cannot be decomposed easily, and they contain large amount of salt. This can also increase the salt in the compost which will negatively affect plants. Therefore, it is recommended to wash the organic waste before composting process in order to minimize the salts content. Furthermore, more time should be given to the compost to complete the decomposition process.

Further studies are required to compare the long-term effects of both animal manure and compost on the soil properties, texture, soil pH and nutrient content. In addition, “Petiole”, a phone application, which used to measure the leaf area, provided accurate measurements, and it is recommended for research purposes in the future (figure 1).

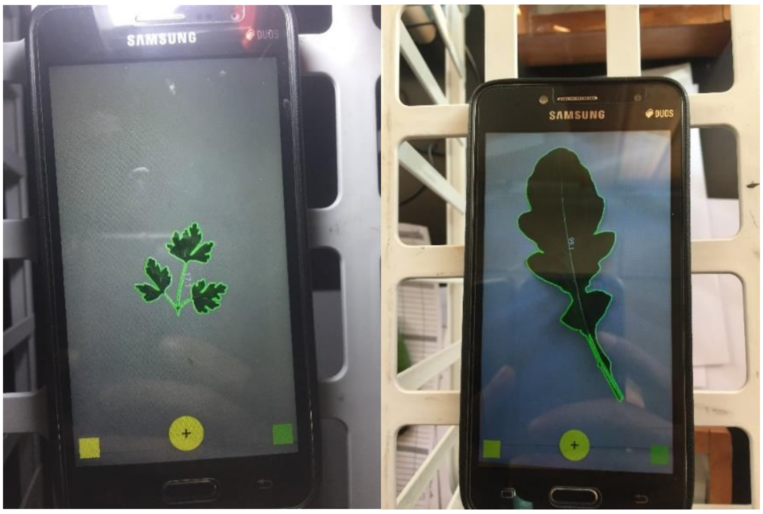

Fig. (1): The calculation of leaf area using Petiole phone application.

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پوختە

ل دویف ئەنجامێن شروڤەکرنا کومپوستی یێ کو هاتیە بەرهەم ئینان ل کارگەها کواشێ یا گلێشی و تێدا دیاربووی کو رێژا کانزاییێن ب سەنگ لناڤدا یا زێدەبوو ب تایبەتی (lead, cadmium, copper, nickel , chromium, cobalt and zinc)، ئەڤ ڤەکولینە هاتە ئەنجامدان لسەر ٣ جورێت زەرزەواتێن بەلگی (جەرجیر وکەرەفس و بەقلی) ژبو دیارکرنا رێژا کانزاییێن ب سەنگ دناڤ بەلگێن واندا. ئەنجامان دیارکر کو دەرئەنجامانێن لسەر رووەکاندا دجیاوازبوون لدویف کارلێکێن هاتینە ب کارئینان دڤێ لێکولینێ دا بو هەر ئێک ژ تێگوهورێن هاتینە بکارئینان. دیاربو کو ئەو رووەکێن هاتینە کارلێک کرن ب پەینێ گیانەوەری دسەرکەفتی بوون لسەر وان رووەکێن کارلێک کرین ب کومپوستی بو زوربەیا تێگوهورا. بەلێ جیاوازیەکا بەرچاڤ (بەرکەفتی) دگەل وان رووەکان دا نەبوو ئەوێن هاتینە کارلێک کرن بـ ٦ و ٩ لیتر/ م٢ یێن کومپوستی. رێژا کانزایێن ب سەنگ دناڤ هەمی نموونان‌دا لدویف ستاندارتێن یاسایا خوارنێ یا ئەوروپی بوو ژبلی (کرومیوم) چونکی دیاربوو کو یێ ژەهراوی بوو دناڤ ئێک ژ نموونێن کەرەفسێ دا (٠,٥٣ ملغم/ کغم) وب کێر خوارنا مروڤان ناهێت. یا سەرنج راکێش ئەوبوو کو ئەو نموونێت نەهاتینە کارلێک کرن ب کومپوستی دیارکر کو رێژا کانزاییێن ب سەنگ دناڤدا یا نێزیکی وێ رێژێ بوو ئەوا دناڤ وان نموونان‌دا ئەوێت هاتینە کارلێک کرن ب کومپوستی، ئەڤەژی وێ چەندێ دیاردکەت کو ئەڤ رێژا کانزایا دناڤ وان نموونان‌دا دیاربووی ژ ژێدەرەکێ دی هاتیە ژبلی کومپوستی. ئەڤ ڤەکولینە بکارئینانا دروست دوپات دکەت و رێکێ ل بکارئینانا رێژێت زیانبەخش یێن پێشبینیکری د پاشەروژێدا دگریت.

الخلاصة

اعتماداً على نتائج تحليل الكومبوست المنتج في معمل نفايات كواشي والذي اظهر زيادة في كميات العناصر الثقيلة (وخاصة الرصاص والكادميوم والنحاس والنيكل والكروم والكوبلت والزنك)، اجريت هذه الدراسة على ثلاثة انواع من الخضراوات الورقية (الجرجير والكرفس والسلق) وذلك لتحديد كمية العناصر الثقيلة في اوراقها. اظهرت النتائج بأن استجابة النباتات قد اختلفت حسب المعاملات المستخدمة في الدراسة لكل من المتغيرات المدروسة. تبين ان النباتات المعاملة بالسماد الحيواني كانت متفوقة على تلك التي عوملت بالكومبوست لاغلب المتغيرات. بيد انها لم تختلف معنوياً عن النباتات التي عوملت بـ ٦ و٩ لتر/ م٢. محتوى العناصر الثقيلة في جميع العينات كانت متوافقة مع قانون الغذاء الاوروبي ماعدا الكروم حيث ظهر بانه سام في احدى عينات الكرفس (٠,٥٣ ملغم/ كغم) ولا يمكن استخدامها للاستهلاك البشري. من المثير للاهتمام ان العينات التي لم تعامل بالكومبوست اظهرت نسب قريبة من التي عوملت بالكومبوست من حيث احتوائها على العناصر الثقيلة مما يدل على انها قد تلوثت من مصدر اخر غير الكومبوست. هذه الدراسة تؤكد على الاستخدام الصحيح للكومبوست وتمنع استخدام الكميات الضارة المحتملة في المستقبل.