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Research Article

# Lead, Nickel and Copper Concentration and Related Factors in Some Uncooked Vegetables Irrigated by Wastewater

Dilshad Ganjo Ahmad* and Tablo Abdul-Raheem Ahamd Gaf

*Department of Biology, College of Science, University of Salahaddin-Erbil, Iraq.

**Abstract:** Population density of Erbil City, Northern Iraq (where this work was carried out) estimated as more than 2 million. The sewage discharge of the city may reach 77760$m^3$/ day during low level and 108000$m^3$/ day during high-level periods. About 225 hectares of scattered farmlands are used by local farmers for production of uncooked vegetables for local need, all of which are irrigated by untreated sewage water. In the present work, about 28 physical and chemical variables those related to sewage water quality were assessed on fortnightly bases for 7 months. Some toxic heavy metals, namely; Pb, Ni and Cu bioaccumulation rates in sewage, soil and some uncooked vegetables in five different locations/ farms were followed up (only bioaccumulation rates of Pb, Ni and Cu in lettuce, cress, dill and radish are given here) (Full data can be obtained from both authors). Onset results revealed that Pb, Ni and Cu bioaccumulation rates calculated for lettuce, cress, dill and radish were surpassed maximum permissible levels (MPL). However, the bioaccumulation ranges calculated for lettuce, cress, dill and radish respectively were; lead (3.01-6.72mg/ kg/ dwt), (3.03-6.52mg/ kg/ dwt), (0.48-2.74mg/ kg/ dwt) and (0.41-3.00mg/ kg/ dwt); nickel (1.01-3.92mg/ kg/ dwt), (4.03-7.99mg/ kg/ dwt), (0.37-3.98mg/ kg/ dwt) and (1.00-3.95mg/ kg/ dwt) and copper (8.02-15.26mg/ kg/ dwt), (7.20-13.62mg/ kg/ dwt),(6.35-10.37mg/ kg/ dwt), (2.01-5.94mg/ kg/ dwt). The studied vegetables were showed different modes concerning heavy metal accumulation rates.

**Keywords:** Wastewater, Pb, Ni, Cu, Bioaccumulation, Lettuce, Cress, Dill and Radish.

## 1. Introduction

Sewage or wastewater is a dilute mixture of various wastes from residential, commercial, industrial and other human activities. Sewage, in general, contains toxicants, organic and inorganic matter among which are heavy metals [1]. Extensive use of sewage water for irrigation purpose has resulted in an upsurge of such metals in soils and various crops, due to chance of accumulation of these metals, which ultimately resulted in clinical problems and chronic intoxication in human beings [2].

Toxicity of ingested heavy metals has been an important human health issue for decades. The prevalence of contamination from both natural and anthropogenic sources has increased concern about the health effects of chronic low-level permanently exposures. Many researchers have shown that some common vegetables are capable of accumulating high levels of metals from the soil [3].

Some heavy metal such as Cu is essential in plant nutrition; meanwhile others like Pb and Ni do not play any significant role in the plant physiology. Plants growing in a polluted environment can accumulate the toxic metals at high concentration causing chronic intoxication in human when consumed excessive levels of such metals [4].

It is obvious that Erbil's (Northern Iraq) sewage water is much polluted, assessed as causing irrigation problems and health risks for the community. Farmers here irrigate about 225 hectares by sewage water without any pretreatment for the production of uncooked vegetables which consumed by about two million people as an important part of the human diet, which contains proteins, vitamins, minerals. Therefore the present study was designed and the objective was to highlight on bioaccumulation rate of Pb, Ni and Cu in

*Corresponding author:
E-mail: environment@mapcom.org.

four uncooked vegetables namely; lettuce (*Lactuca sativa*), cress (*Lepidium sativum*), dill (*Anethum graveolens*) and radish (*Raphanus sativus*).

## 2. Methodology

### 2.1 The Study Area

The main sewage canal of Erbil City, Northern Iraq with surrounding farmlands, Fig. 1, Figs. 2 and 3 was selected for the purpose of this study. The area is inhabited by 350 civil; most of them are engaging with agricultural activities. Untreated wastewater here using diesel water pumps is used for irrigation of 225 hectares of vegetables that consumed without cooking Figs. 4 and 5.

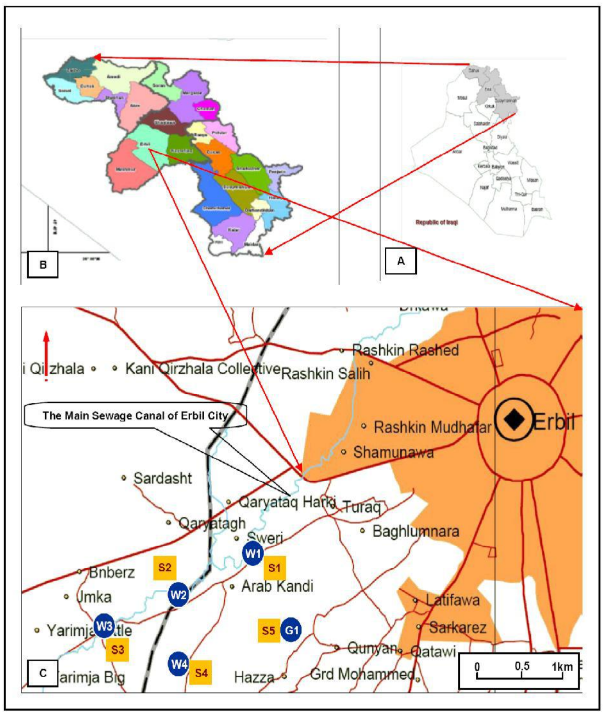


**Fig. 1. Map showing; A) Republic of Iraq, B) Kurdistan Region of Iraq/ Northern Iraq and C) Erbil city, location of sewage canal, soil and vegetable sampling sites is indicated.**

**Fig. 2. Main Canal of the Sewage Water with Lifting Diesel Pumps.**

**Fig. 3. Main Canal of the Sewage Water with Lifting Diesel Pumps.**

**Fig. 4. Vast Farms for Uncooked Vegetable.**

**Fig. 5. Vast Farms for Uncooked Vegetable.**

### 2.2 Sample Collection and Frequency

All samples including; Pb, Ni and Cu in studying vegetables at selected sites were collected according to a regular schedule for seven months (November and December 2008, until May 2009) at fortnightly interval periods. An extra attention was paid to the accumulated levels of Pb, Ni and Cu in edible parts of four uncooked vegetables namely; lettuce (*L. sativa*), cress (*L. sativum*), dill (*A. graveolens*) and radish (*R. sativus*). A comparison was made between the level of heavy metals in vegetables irrigated with sewage water from one hand and vegetables irrigated with clean water (i.e. Groundwater as a reference site) from the other hand. Meanwhile, the seasonal variation in heavy metals in the selected vegetables was followed up.

### 2.3 Vegetable Sampling

Good quality fresh samples of the studied vegetables (commonly eaten parts), were collected from nearer farmlands. Vegetable Samples from farms were selected using random sampling procedure. The edible parts of vegetables were collected by hand and carefully packed in polyethylene bags, samples were returned back to the laboratory as soon as possible.

### 2.4 Digestion of Vegetable Samples and Heavy Metal Analysis

Vegetable samples were digested according to [5], briefly; a bulk sample from each farm was homogenized, and powdered vegetable sample was transferred to porcelain crucibles or Pyrex glass beakers. Then placed in a cool muffle furnace, the temperature was then increased gradually to 550ºC for 5 hours. After cooling, the cooled ash was dissolved in 5ml 2N hydrochloric acid (HCl) and the volume was completed to 50ml using deionized (DI) water. The concentration of lead, nickel and copper were determined by atomic absorption spectrophotometer (PHILIPS Model SP9) equipped with hollow-cathode lamp (electrodes discharge source lamp) according to standard instrumental condition.

### 2.5 Experimental Design and Statistical Analysis

Mean and ± SD were calculated for each variable. Randomized Complete Block Design (RCBD) was used for the analysis of the data by using the Microsoft program (STATGRAF Ver. 4). LSD test was used to determine the presence or absence of statistical differences:

a) Between the sites as a spatial variation and

b) Between the sampling date intervals as a temporal variation at probabilities 95% and 99%.

## 3. Results

Generally, results, Tables 1 to 12 were revealed that Pb, Ni and Cu bioaccumulation rates calculated for lettuce, cress, dill and radish were surpassed maximum permissible levels (MPL). Significant spatial-temporal differences ($P<0.01$) were always noted between sites and dates of sampling. The studied vegetables were shown different modes concerning the rate of heavy metal accumulation.

The accumulation rate of lead, Tables 1 to 4 was ranging from 3.01- 6.72mg/ kg/ dwt, 3.03-6.52mg/ kg/ dwt, 0.48-2.74mg/ kg/ dwt and 0.41-3.00mg/ kg/ dwt calculated for lettuce, cress, dill and radish respectively. Generally, the bioaccumulation rates of Pb in lettuce were slightly higher than cress followed by radish then in dill vegetables in its order of concentration.

Nickel toxicity causes an interveinal chlorosis that looks very similar to manganese deficiency, is described as poor growth accompanied by chlorosis followed by necrosis [6]. The bioaccumulation levels of Ni (Tables 5 to 8) were ranging from; (1.01-3.92mg/ kg/ dwt), (4.03-7.99mg/ kg/ dwt), (0.37-3.98mg/ kg/ dwt) and (1.00-3.95mg/ kg/ dwt) measured for lettuce, cress, dill and radish respectively. It seems that the bioaccumulation rate of Ni in cress was higher than dill followed by radish then in lettuce vegetable in its order of concentration. These rates seem to be higher than the maximum allowable limits of (0.5mg/ kg/ dwt) in the vegetables as recommended by [7]. Spatial and temporal variation between studied sites and sampling dates were clear.

**Table 1. Lead bioaccumulation (mg/ kg/ dwt) in dill vegetables collected from different locations.**

| Site | 2007 | | | 2008 | | | | | | | | | | Mean | ±SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nov. | December | | January | | February | | March | | April | | May | | | |
| W1 | 1.75 | 2.05 | 1.05 | 1.87 | 1.66 | 1.57 | 1.56 | 0.68 | 1.98 | 2.46 | 2.33 | 2.74 | NA | 1.81 | 0.57 |
| W2 | 1.03 | 1.03 | 1.04 | 0.97 | 0.64 | 0.95 | 0.86 | 1.39 | 1.81 | 1.78 | 2.49 | 1.65 | NA | 1.30 | 0.53 |
| W3 | 0.59 | 1.25 | 1.94 | 2.74 | 0.53 | 1.46 | 0.73 | 1.80 | 2.53 | 1.04 | 0.71 | 0.92 | NA | 1.35 | 0.75 |
| W4 | 0.67 | 0.71 | 0.77 | 1.74 | 2.02 | 1.98 | 0.83 | 1.65 | 1.65 | 1.09 | 0.50 | 0.55 | NA | 1.18 | 0.58 |
| G1 | 0.64 | 1.26 | 0.84 | 1.12 | 1.97 | 1.06 | 0.71 | 0.48 | 0.50 | 1.65 | 1.53 | 0.72 | NA | 1.04 | 0.48 |
| Mean | 0.94 | 1.26 | 1.13 | 1.69 | 1.37 | 1.40 | 0.94 | 1.20 | 1.69 | 1.60 | 1.51 | 1.32 | - | 1.34 | 0.63 |
| ±SD | 0.49 | 0.50 | 0.47 | 0.70 | 0.73 | 0.41 | 0.35 | 0.59 | 0.75 | 0.58 | 0.91 | 0.90 | - | 0.29 | - |
| LSD (0.01) for studied sites = 0.653 | | | | | LSD (0.01) for sampling dates = 1.012 | | | | | | NA Means not available | | | | |

**Table 2. Lead bioaccumulation (mg/ kg/ dwt) in radish vegetables collected from different locations.**

| Site | 2007 | | | 2008 | | | | | | | | | | Mean | ±SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nov. | December | | January | | February | | March | | April | | May | | | |
| W1 | 0.52 | 2.50 | 1.28 | 1.37 | 1.59 | 2.78 | 3.00 | 1.09 | 2.06 | 2.02 | 0.51 | NA | NA | 1.70 | 0.85 |
| W2 | 1.05 | 1.01 | 2.01 | 2.03 | 1.08 | 1.01 | 1.36 | 1.54 | 1.74 | 2.39 | 1.78 | NA | NA | 1.55 | 0.48 |
| W3 | 2.35 | 2.06 | 1.14 | 1.13 | 1.32 | 1.42 | 2.02 | 1.69 | 2.88 | 2.65 | 0.73 | NA | NA | 1.76 | 0.69 |
| W4 | 1.26 | 1.77 | 0.41 | 1.51 | 2.01 | 0.51 | 0.50 | 0.88 | 2.01 | 1.47 | 1.08 | NA | NA | 1.22 | 0.59 |
| G1 | 1.36 | 1.87 | 0.92 | 0.84 | 0.87 | 1.02 | 1.77 | 2.03 | 1.54 | 1.53 | 1.03 | NA | NA | 1.34 | 0.43 |
| Mean | 1.31 | 1.84 | 1.15 | 1.38 | 1.38 | 1.35 | 1.73 | 1.44 | 2.05 | 2.01 | 1.03 | - | - | 1.51 | 0.34 |
| ±SD | 0.67 | 0.54 | 0.58 | 0.45 | 0.44 | 0.86 | 0.91 | 0.46 | 0.51 | 0.52 | 0.48 | - | - | 0.23 | - |
| LSD (0.01) for studied sites = 0.505 | | | | | LSD (0.01) for studied sites = 0.749 | | | | | | NA Means not available | | | | |

**Table 3. Lead bioaccumulation (mg/ kg/ dwt) in lettuce vegetables collected from different locations.**

| Site | 2007 | | | 2008 | | | | | | | | | | Mean | ±SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nov. | December | | January | | February | | March | | April | | May | | | |
| **W1** | 4.41 | 4.41 | 4.21 | 4.03 | 4.01 | 6.03 | 5.69 | 5.20 | 5.21 | 6.15 | 5.63 | 5.21 | NA | 5.02 | 0.78 |
| **W2** | 4.01 | 4.02 | 5.15 | 5.39 | 5.39 | 6.03 | 6.23 | 6.52 | 4.51 | 5.22 | 4.89 | 4.02 | NA | 5.11 | 0.87 |
| **W3** | 5.81 | 5.65 | 5.42 | 5.36 | 5.01 | 6.36 | 4.21 | 5.33 | 6.07 | 5.81 | 5.23 | 4.02 | NA | 5.36 | 0.69 |
| **W4** | 4.03 | 3.32 | 3.33 | 4.30 | 4.05 | 5.21 | 5.20 | 4.00 | 4.01 | 3.36 | 3.01 | 3.74 | NA | 3.96 | 0.70 |
| **G1** | 3.35 | 3.04 | 3.07 | 3.23 | 5.42 | 5.12 | 5.03 | 5.12 | 4.02 | 4.08 | 3.74 | 3.21 | NA | 4.04 | 0.91 |
| **Mean** | 4.32 | 4.09 | 4.24 | 4.46 | 4.78 | 5.75 | 5.27 | 5.24 | 4.76 | 4.92 | 4.50 | 4.04 | - | 4.70 | 0.53 |
| **±SD** | 0.92 | 1.03 | 1.05 | 0.92 | 0.70 | 0.55 | 0.76 | 0.89 | 0.88 | 1.18 | 1.09 | 0.73 | - | 0.65 | - |

**LSD (0.01) for studied sites = 0.728** | **LSD (0.01) for sampling dates = 1.129** | **NA Means not available**

**Table 4. Lead bioaccumulation (mg/ kg/ dwt) in cress vegetables collected from different locations.**

| Site | 2007 | | | 2008 | | | | | | | | | | Mean | ±SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nov. | December | | January | | February | | March | | April | | May | | | |
| **W1** | 5.72 | 3.23 | 3.21 | 3.32 | 4.43 | 6.65 | 6.12 | 5.20 | 5.21 | 5.03 | 3.75 | NA | NA | 4.72 | 1.21 |
| **W2** | 5.55 | 4.62 | 4.75 | 6.63 | 6.23 | 6.22 | 5.02 | 4.07 | 4.25 | 4.01 | 4.32 | NA | NA | 5.06 | 0.95 |
| **W3** | 4.26 | 4.15 | 5.52 | 5.28 | 6.62 | 6.42 | 6.21 | 6.72 | 4.58 | 4.05 | 5.98 | NA | NA | 5.44 | 1.03 |
| **W4** | 3.22 | 3.73 | 3.74 | 3.03 | 5.22 | 4.01 | 3.22 | 3.03 | 3.85 | 3.96 | 4.63 | NA | NA | 3.79 | 0.68 |
| **G1** | 4.07 | 4.28 | 4.12 | 3.20 | 5.07 | 5.20 | 5.01 | 5.28 | 3.72 | 3.22 | 3.44 | NA | NA | 4.24 | 0.80 |
| **Mean** | 4.57 | 4.00 | 4.27 | 4.29 | 5.52 | 5.70 | 5.12 | 4.86 | 4.32 | 4.06 | 4.43 | - | - | 4.65 | 0.58 |
| **±SD** | 1.05 | 0.54 | 0.90 | 1.59 | 0.89 | 1.10 | 1.20 | 1.39 | 0.60 | 0.64 | 0.99 | - | - | 0.65 | - |

**LSD (0.01) for studied sites = 0.977** | **LSD (0.01) for studied sites = 1.44** | **NA Means not available**

**Table 5. Nickel bioaccumulation (mg/ kg/ dwt) in dill vegetables collected from different locations.**

| Site | 2007 | | | 2008 | | | | | | | | | | Mean | ±SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nov. | December | | January | | February | | March | | April | | May | | | |
| **W1** | 2.53 | 2.75 | 1.75 | 1.69 | 2.00 | 1.02 | 2.08 | 0.54 | 2.82 | 2.61 | 1.54 | 3.62 | NA | 2.08 | 0.85 |
| **W2** | 3.35 | 3.13 | 2.02 | 2.27 | 1.66 | 0.82 | 0.62 | 1.46 | 1.99 | 3.03 | 3.74 | 3.53 | NA | 2.30 | 1.05 |
| **W3** | 3.96 | 1.02 | 1.98 | 1.68 | 1.74 | 1.65 | 2.43 | 2.06 | 3.48 | 3.98 | 3.75 | 1.02 | NA | 2.40 | 1.11 |
| **W4** | 2.10 | 1.02 | 1.78 | 0.71 | 0.78 | 0.37 | 1.21 | 0.65 | 1.54 | 2.74 | 2.71 | 1.70 | NA | 1.44 | 0.79 |
| **G1** | 3.28 | 1.23 | 0.54 | 0.58 | 0.78 | 0.55 | 1.65 | 1.05 | 1.47 | 2.58 | 2.55 | 2.46 | NA | 1.56 | 0.94 |
| **Mean** | 3.04 | 1.83 | 1.61 | 1.39 | 1.39 | 0.88 | 1.60 | 1.15 | 2.26 | 2.99 | 2.86 | 2.47 | - | 1.96 | 1.00 |
| **±SD** | 0.73 | 1.03 | 0.61 | 0.72 | 0.57 | 0.50 | 0.71 | 0.62 | 0.87 | 0.58 | 0.93 | 1.13 | - | 0.43 | - |

**LSD (0.01) for studied sites = 0.558** | **LSD (0.01) for sampling dates = 1.155** | **NA Means not available**

**Table 6. Nickel bioaccumulation (mg/ kg/ dwt) in radish vegetables collected from different locations.**

| Site | 2007 | | | 2008 | | | | | | | | | | Mean | ±SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nov. | December | | January | | February | | March | | April | | May | | | |
| **W1** | 2.04 | 1.49 | 2.81 | 3.52 | 1.65 | 1.53 | 1.62 | 2.07 | 3.52 | 3.08 | 3.55 | NA | NA | 2.44 | 0.86 |
| **W2** | 1.86 | 2.78 | 2.62 | 2.74 | 2.03 | 2.02 | 1.10 | 1.03 | 2.90 | 3.95 | 3.02 | NA | NA | 2.37 | 0.86 |
| **W3** | 3.01 | 1.00 | 1.67 | 1.45 | 2.04 | 2.04 | 3.08 | 2.78 | 3.73 | 3.61 | 2.39 | NA | NA | 2.44 | 0.89 |
| **W4** | 1.57 | 2.04 | 2.69 | 2.21 | 1.75 | 2.10 | 1.73 | 1.03 | 1.02 | 2.91 | 2.98 | NA | NA | 2.00 | 0.67 |
| **G1** | 1.09 | 1.06 | 2.78 | 2.05 | 1.78 | 1.00 | 1.06 | 2.10 | 1.32 | 1.31 | 1.03 | NA | NA | 1.51 | 0.59 |
| **Mean** | 1.91 | 1.67 | 2.52 | 2.39 | 1.85 | 1.74 | 1.72 | 1.80 | 2.50 | 2.97 | 2.59 | - | - | 2.15 | 0.84 |
| **±SD** | 0.71 | 0.75 | 0.48 | 0.78 | 0.17 | 0.47 | 0.82 | 0.76 | 1.25 | 1.02 | 0.97 | - | - | 0.40 | - |

**LSD (0.01) for studied sites = 0.827** | **LSD (0.01) for studied sites = 1.22** | **NA Means not available**

**Table 7. Nickel bioaccumulation (mg/ kg/ dwt) in lettuce vegetables collected from different locations.**

| Site | 2007 | | | 2008 | | | | | | | | | | Mean | ±SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nov. | December | | January | February | | | March | | April | | May | | | |
| **W1** | 3.77 | 3.62 | 3.54 | 3.52 | 2.03 | 2.58 | 2.64 | 3.03 | 3.03 | 3.12 | 3.32 | 3.22 | NA | 3.12 | 0.50 |
| **W2** | 3.82 | 3.12 | 3.04 | 2.04 | 1.23 | 3.06 | 2.07 | 3.04 | 2.03 | 3.04 | 3.92 | 2.35 | NA | 2.73 | 0.80 |
| **W3** | 3.72 | 2.06 | 2.55 | 1.30 | 1.36 | 2.04 | 1.01 | 3.15 | 3.87 | 2.07 | 3.53 | 3.04 | NA | 2.47 | 0.99 |
| **W4** | 1.02 | 1.22 | 1.02 | 2.03 | 2.31 | 1.01 | 3.01 | 2.12 | 1.07 | 2.09 | 2.04 | 1.02 | NA | 1.66 | 0.68 |
| **G1** | 2.01 | 1.13 | 2.13 | 2.02 | 2.01 | 2.01 | 1.01 | 2.02 | 2.02 | 3.02 | 3.03 | 2.04 | NA | 2.04 | 0.59 |
| **Mean** | 2.87 | 2.23 | 2.46 | 2.18 | 1.79 | 2.14 | 1.95 | 2.67 | 2.40 | 2.67 | 3.17 | 2.33 | - | 2.41 | 0.39 |
| **±SD** | 1.28 | 1.12 | 0.96 | 0.81 | 0.47 | 0.77 | 0.92 | 0.55 | 1.08 | 0.54 | 0.71 | 0.88 | - | 0.57 | - |

**LSD (0.01) for studied sites = 0.758** | **LSD (0.01) for sampling dates = 1.175** | **NA Means not available**

**Table 8. Nickel bioaccumulation (mg/ kg/ dwt) in cress vegetables collected from different locations.**

| Site | 2007 | | | 2008 | | | | | | | | | | Mean | ±SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nov. | December | | January | February | | | March | | April | | May | | | |
| W1 | 7.98 | 5.04 | 6.95 | 6.98 | 7.61 | 5.03 | 5.04 | 6.02 | 6.06 | 7.74 | 7.03 | NA | NA | 6.50 | 1.12 |
| W2 | 6.67 | 7.05 | 6.94 | 6.40 | 6.51 | 6.72 | 4.86 | 5.94 | 7.86 | 7.84 | 5.97 | NA | NA | 6.62 | 0.86 |
| W3 | 7.06 | 7.99 | 7.87 | 5.59 | 6.54 | 5.07 | 5.52 | 5.36 | 7.83 | 6.95 | 7.28 | NA | NA | 6.64 | 1.09 |
| W4 | 5.11 | 5.16 | 5.18 | 4.03 | 4.22 | 4.03 | 6.75 | 6.08 | 6.08 | 5.04 | 5.00 | NA | NA | 5.15 | 0.88 |
| G1 | 5.87 | 5.93 | 4.75 | 4.52 | 4.80 | 5.73 | 5.76 | 5.54 | 6.58 | 6.53 | 4.97 | NA | NA | 5.54 | 0.70 |
| Mean | 6.54 | 6.23 | 6.34 | 5.51 | 5.94 | 5.32 | 5.58 | 5.79 | 6.88 | 6.82 | 6.05 | - | - | 6.09 | 0.53 |
| ±SD | 1.10 | 1.27 | 1.32 | 1.24 | 1.39 | 0.99 | 0.75 | 0.32 | 0.90 | 1.13 | 1.09 | - | - | 0.69 | - |
| LSD (0.01) for studied sites = 1.019 | | | | | LSD (0.01) for studied sites = 1.51 | | | | | | | NA Means not available | | | |

**Table 9. Copper bioaccumulation (mg/ kg/ dwt) in dill vegetables collected from different.**

| Site | 2007 | | | 2008 | | | | | | | | | | Mean | ±SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nov. | December | | January | February | | | March | | April | | May | | | |
| W1 | 7.81 | 8.82 | 8.96 | 9.73 | 9.72 | 9.62 | 8.41 | 9.80 | 8.72 | 8.83 | 9.53 | 10.37 | NA | 9.19 | 0.72 |
| W2 | 9.72 | 9.03 | 10.05 | 8.38 | 8.98 | 8.03 | 7.36 | 7.53 | 9.26 | 8.36 | 9.06 | 9.99 | NA | 8.81 | 0.90 |
| W3 | 10.06 | 8.38 | 8.45 | 8.25 | 7.04 | 8.08 | 9.40 | 10.02 | 9.36 | 9.24 | 9.12 | 9.82 | NA | 8.94 | 0.91 |
| W4 | 8.06 | 8.65 | 8.98 | 7.31 | 8.33 | 7.04 | 7.02 | 7.36 | 7.01 | 9.25 | 8.13 | 8.31 | NA | 7.95 | 0.79 |
| G1 | 8.04 | 6.36 | 6.35 | 7.03 | 7.04 | 7.03 | 8.06 | 8.45 | 8.02 | 8.53 | 7.03 | 8.79 | NA | 7.56 | 0.85 |
| Mean | 8.74 | 8.25 | 8.56 | 8.14 | 8.22 | 7.96 | 8.05 | 8.63 | 8.47 | 8.84 | 8.57 | 9.46 | - | 8.49 | 1.02 |
| ±SD | 1.06 | 1.08 | 1.36 | 1.06 | 1.19 | 1.06 | 0.93 | 1.24 | 0.98 | 0.40 | 1.01 | 0.87 | - | 0.70 | - |
| LSD (0.01) for studied sites = 0.893 | | | | | LSD (0.01) for sampling dates = 1.384 | | | | | | | NA Means not available | | | |

**Table 10. Copper bioaccumulation (mg/ kg/ dwt) in radish vegetables collected from different locations.**

| Site | 2007 | | | 2008 | | | | | | | | | | Mean | ±SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nov. | December | | January | February | | | March | | April | | May | | | |
| W1 | 5.04 | 4.75 | 4.52 | 3.15 | 2.51 | 2.80 | 3.04 | 3.02 | 4.45 | 4.33 | 4.03 | NA | NA | 3.78 | 0.89 |
| W2 | 5.88 | 4.90 | 4.82 | 3.63 | 3.56 | 3.45 | 3.45 | 5.94 | 5.86 | 5.91 | 5.90 | NA | NA | 4.85 | 1.12 |
| W3 | 5.38 | 5.21 | 3.30 | 3.30 | 3.31 | 2.05 | 3.09 | 4.08 | 4.14 | 3.81 | 4.04 | NA | NA | 3.79 | 0.95 |
| W4 | 2.08 | 2.01 | 3.10 | 4.07 | 3.17 | 2.16 | 2.05 | 2.14 | 3.05 | 4.37 | 4.05 | NA | NA | 2.93 | 0.91 |
| G1 | 2.02 | 3.02 | 3.03 | 3.04 | 2.02 | 2.41 | 3.02 | 3.15 | 3.07 | 3.01 | 3.36 | NA | NA | 2.83 | 0.46 |
| Mean | 4.08 | 3.98 | 3.75 | 3.44 | 2.91 | 2.58 | 2.93 | 3.67 | 4.12 | 4.28 | 4.28 | - | - | 3.64 | 1.13 |
| ±SD | 1.68 | 1.24 | 0.76 | 0.37 | 0.57 | 0.51 | 0.47 | 1.29 | 1.04 | 0.95 | 0.85 | - | - | 0.73 | - |
| LSD (0.01) for studied sites = 0.857 | | | | | LSD (0.01) for studied sites = 1.271 | | | | | | | NA Means not available | | | |

**Table 11. Copper bioaccumulation (mg/ kg/ dwt) in lettuce vegetables collected from different locations.**

| Site | 2007 | | | 2008 | | | | | | | | | | Mean | ±SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nov. | December | | January | February | | | March | | April | | May | | | |
| W1 | 7.98 | 5.04 | 6.95 | 6.98 | 7.61 | 5.03 | 5.04 | 6.02 | 6.06 | 7.74 | 7.03 | NA | NA | 6.50 | 1.12 |
| W2 | 6.67 | 7.05 | 6.94 | 6.40 | 6.51 | 6.72 | 4.86 | 5.94 | 7.86 | 7.84 | 5.97 | NA | NA | 6.62 | 0.86 |
| W3 | 7.06 | 7.99 | 7.87 | 5.59 | 6.54 | 5.07 | 5.52 | 5.36 | 7.83 | 6.95 | 7.28 | NA | NA | 6.64 | 1.09 |
| W4 | 5.11 | 5.16 | 5.18 | 4.03 | 4.22 | 4.03 | 6.75 | 6.08 | 6.08 | 5.04 | 5.00 | NA | NA | 5.15 | 0.88 |
| G1 | 5.87 | 5.93 | 4.75 | 4.52 | 4.80 | 5.73 | 5.76 | 5.54 | 6.58 | 6.53 | 4.97 | NA | NA | 5.54 | 0.70 |
| Mean | 6.54 | 6.23 | 6.34 | 5.51 | 5.94 | 5.32 | 5.58 | 5.79 | 6.88 | 6.82 | 6.05 | - | - | 6.09 | 0.53 |
| ±SD | 1.10 | 1.27 | 1.32 | 1.24 | 1.39 | 0.99 | 0.75 | 0.32 | 0.90 | 1.13 | 1.09 | - | - | 0.69 | - |
| LSD (0.01) for studied sites = 1.25 | | | | | LSD (0.01) for sampling dates = 1.937 | | | | | | | NA Means not available | | | |

**Table 12. Copper bioaccumulation (mg/ kg/ dwt) in cress vegetables collected from different locations**

| Site | 2007 | | | 2008 | | | | | | | | | | Mean | ±SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nov. | December | | January | February | | | March | | April | | May | | | |
| W1 | 9.34 | 10.75 | 9.06 | 9.24 | 9.17 | 9.07 | 8.95 | 10.24 | 11.82 | 12.87 | 12.32 | NA | NA | 10.26 | 1.46 |
| W2 | 10.73 | 10.65 | 11.02 | 9.33 | 7.03 | 8.13 | 8.06 | 10.69 | 9.61 | 9.34 | 13.62 | NA | NA | 9.84 | 1.80 |
| W3 | 10.37 | 13.37 | 9.93 | 10.74 | 9.55 | 9.51 | 8.77 | 9.95 | 11.84 | 11.71 | 10.91 | NA | NA | 10.60 | 1.31 |
| W4 | 9.03 | 8.12 | 8.51 | 8.91 | 8.63 | 7.32 | 7.20 | 9.65 | 9.20 | 10.36 | 10.50 | NA | NA | 8.86 | 1.08 |
| G1 | 7.23 | 8.21 | 8.24 | 9.01 | 9.02 | 8.92 | 8.34 | 7.20 | 7.75 | 9.31 | 8.51 | NA | NA | 8.34 | 0.72 |
| Mean | 9.34 | 10.22 | 9.35 | 9.44 | 8.68 | 8.59 | 8.26 | 9.54 | 10.04 | 10.72 | 11.17 | - | - | 9.58 | 0.90 |
| ±SD | 1.37 | 2.17 | 1.13 | 0.74 | 0.98 | 0.87 | 0.69 | 1.37 | 1.77 | 1.55 | 1.93 | - | - | 0.95 | - |
| LSD (0.01) for studied sites = 1.251 | | | | | LSD (0.01) for studied sites = 1.855 | | | | | | | NA Means not available | | | |

The bioaccumulation levels of Cu (Tables 9 to 12) were ranging from; (8.02-15.26mg/ kg/ dwt), (7.20-13.62mg/ kg/ dwt), (6.35-10.37mg/ kg/ dwt) and (2.01-5.94mg/ kg/ dwt) recorded for lettuce, cress, dill and radish respectively. It seems that the bioaccumulation rates of Cu in lettuce were higher than cress followed by dill then in radish vegetables in its order of concentration. These rates seem to be slightly and/or comparable to the maximum allowable limits of (10.0mg/ kg/ dwt) in the vegetables as recommended by [7].

## 4. Discussion

The range of lead bioaccumulation in all studied vegetables seems to be higher than the maximum permissible levels (MPL) recommended by [7] which it is (0.3mg/ kg/ dwt). However, similar ranges of lead bioaccumulation were calculated in different vegetables irrigated with sewage water by [8]. Statements that of [9] may confirm the present results, however, he demonstrated that the Pb accumulation in vegetables depends upon several factors, among them the distance of farms from the roadsides, soil's characteristics, microbial activity, yard manure, fertilizers, pesticides and sewage sludge. The bioaccumulation rates of Pb in lettuce were much higher than cress followed by radish then in dill in its order of concentration. This as outlined by [4] may be attributed to that metal accumulation in plant depends on genotype differences in plant uptake of mineral elements. The differences between the studied sites may be attributed to the solubility of lead in different soil types in the studied area. However, the solubility of lead known to increase with a decrease in soil pH, and hence plant uptake is higher in acidic soils than in calcareous soils [10]. The same conclusion can be given for the present results.

It is obvious that bioaccumulation rates of Ni in the present study were much less than the level of (67.9mg/ kg/ dwt) recorded by [11], while they were greater than levels of (<1mg/ kg/ dwt) calculated by [12] in vegetables irrigated by untreated sewage water. On the other hand, present results were comparable to those recorded by [13]. Statements that of [14] may confirm the present results, however, they stated that; some vegetable species tolerate high levels of heavy metal (e.g. Nickel) content in soil. However, higher concentrations of these heavy metals are stored in their leaves without the plant being damaged. Meanwhile, [4] concluded that; vegetable species and varieties differ widely in their abilities to absorb, accumulate and tolerate heavy metals. Spatial and temporal variation between studied sites and sampling dates may be due to changes in temperature, pH of the soil which affects the availability of metal uptake by plants [15].

Similar Cu bioaccumulation rates as concluded from the present study in uncooked vegetables were recorded by [16]. While the present Cu bioaccumulation rates seem to be slightly higher and/or comparable to levels of (4-15mg/ kg/ dwt) records by [12] and were much less than the value of (73.3mg/ kg/ dwt) measured by [17] in some uncooked vegetables. One possible deficiency of Cu in the plant as concluded by [18] is due to its preferential accumulation in roots. However, [14] outlined that cress plant tolerates relatively high levels of copper in the soil, thus it can be used as soil purifiers. On the other hand, [19] demonstrated that; broadleaf vegetables and herbs accumulated greater concentrations of most heavy metals. Moreover, [10] explained that; vegetable species accumulate different metals depending on environmental conditions, metal type and plant available forms of heavy metals. Furthermore, metal uptake differences by the vegetables as stated by [20] are attributed to plant differences in tolerance to heavy metals. These can be concluded from the present study.

## 5. Conclusion

Generally, present results showed that the Pb concentration in concerned uncooked vegetables was surpassing the maximum permissible levels (MPL). The accumulated concentration of Ni in all studied vegetables was much higher than the maximum permissible levels (MPL). Always the Cu concentrations in the studied vegetable tissues were either below or comparable to the maximum permissible levels (MPL). The Pb, Ni and Cu content in green leafy vegetables (i.e. Lettuce, cress and dill) was much higher than deep/ large rooted plants (i.e. Radish). The uptake rate of Cu in vegetables in contrast to Pb and Ni was higher during March, May and April.

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