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Studies on Lead (Pb) in Some Soils of Qualubeya Governorate

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Abstract

A survey study was conducted to investigate contamination with lead (Pb) due to irrigation with waste water for several years in Al-Gabal Al-Asfar, Qualubeya governorate, Egypt. Five locations were sampled. Lettuce and cabbage plants were also sampled. The investigated soils were contaminated with Pb at high levels but not exceeding the permissible limits. Total and DTPA-extractable Pb decreased in soil with depth of sampling. Lead in cabbage and lettuce were greater in roots than shoots. Concentrations of lead in the edible parts of cabbage and lettuce exceeded the maximum level of lead in leafy vegetables which is 0.1 mgkg^{-1}. Values of calculated bioaccumulation factor (BAF), biological concentration factor (BCF) and translocation factor (TF) show that cabbage and lettuce are excluders as well as none-phytoextractors for lead but they accumulate most of lead in roots than in shoots. Values of health risk assessment were extremely low. Eventually; consuming such contaminated plants with lead may affect severely human health particularly on the long term.

Keywords: Lead, Contamination, Health risk assessment, Translocation factor, bioaccumulation factor, biological concentration factor, Al-Gabal Al-Asfar .

Introduction

Pollution is an introduction of different contaminants to our natural environment causing adverse changes rendering environment dangerous or unfit for human life **(Yusuf and Oluwole, 2009)**. There are many sources of soil pollution with heavy metals including the use of excessive doses of fertilizers and pesticides, quarrying sites, disposal of hazardous wastes **(Kabata-Pendias and Mukherjee, 2007; Gebreyesus, 2014)** as well as irrigation with waste, sewage and industrial waste waters **(Balkhair and Ashraf, 2016).**

The increase in using sewage waters is associated with the increase in population **(Qadir *et al.*, 2010)**. Through bioaccumulation of heavy metals in the environment affect entire ecosystems and pose threats to the environment and public health (**Joseph *et al.*, 2019; Fang *et al.*, 2020; He *et al.*, 2020**). Heavy metals are typically regarded as the most toxic to humans and animals. Adverse human health effects associated with exposure to them, even at low concentrations, are diverse and include, but not limited to, neurotoxic and carcinogenic actions (**ATSDR, 2003a, 2003b, 2007, 2008; Castro-González and Méndez-Armenta, 2008; Jomova and Valko, 2011; Tokar *et al.*, 2011**).

Wastewaters content a variety of trace elements, including lead (Pb), copper (Cu), zinc (Zn), boron (B), cobalt (Co), chromium (Cr), arsenic (As), molybdenum (Mo), and manganese (Mn), as identified by **(Balkhair and Ashraf 2016)**. The continuous use of treated and untreated wastewater causes accumulation of heavy metals in soils **(Khan *et al.*, 2008; Ullah *et al.*, 2012).** Soils accumulate heavy metals from both natural occurrences and human-related activities within agricultural ecosystems.

The soil contamination with heavy metals such as Cd, Cu, Pb and Ni recorded a significant rise in recent decades. This increase is attributed to the application of agricultural fertilizers and pesticides, disposal of municipal waste, mining activities, vehicular emissions, smelting, manufacturing processes, and industrial discharges. The swift pace of global industrial growth has heightened the risk of heavy metal pollution in the environment. Hasty industrial expansion coupled with random urban growth, as well as the prolonged application of substantial quantities of fertilizers and pesticide use have led to the buildup of hazardous substances in soil, water, and atmosphere **(Kishan *et al*. 2014; Kumar *et al*. 2015; Rodriguesa *et al.* 2017).**

Natural sources of heavy metals in the environment are generally of minor concern **(Dixit *et al.*, 2015).** Soils naturally contain these metals due to their geological origins. These metals can negatively impact plant life and microorganisms. Approximately 95% of the heavy metals found in soil originate from igneous rocks, with the remaining 5% coming from sedimentary rocks, according to **(May *et al.*, 2016).** Typically, basaltic igneous rocks are abundant in heavy metals like Cu, Ni and (Co, and shales predominantly contain Pb, Cu, Zn Mn and Cd. Heavy metals are introduced into the soil through various natural mechanisms, including meteoric, biogenic, terrestrial, and volcanic activities, as well as through erosion, leaching, and surface winds, as described by **(Muradoglu *et al.*, 2015).** Plants cultivated in soils irrigated with wastewater exhibit significantly elevated levels of heavy metals compared with those grown in non-contaminated soils (**Khan *et al.*, 2008).** The practice of irrigating with treated and untreated wastewater led to increased levels of Pb, Ni and Cd in the edible parts of vegetables, posing a potential long-term health hazard.

The main target of this study is to evaluate levels of lead in the soils irrigated with waste water for several years and the implications on plants grown. Evaluation of human risk due to consumption of plants that contain high Pb is also implicated.

Materials and Methods

Site Description and Sampling:

Soils, waters and plants were sampled from five different locations irrigated with sewage effluent waters in Al-Gabal Al-Asfar, Qualubia governorate, Egypt. Soil samples were collected from each location at three different depths, *i.e.* 0-10, 10-20 and 20- 40 cm.

Soil Analysis:

Air dried soil samples were crushed and sieved through a 2 mm, then physical and chemical properties were determined according to **Gupta (2009).** Regarding to the content of HMs; lead was extracted from the investigated soil samples using DTPA **(Lindsay and Norvell, 1978)** while, the total content of lead determined through digestion of the aforementioned soil samples with tri-acid mixture according to **Sahrawat *et al.* (2002).**

Water Analysis:

Water samples were collected from the study area in sterilized glass containers and transported to the laboratory under controlled temperature conditions. The physical and chemical properties of the water, including Electrical Conductivity (EC) and pH, were determined following the standard methods described by **Gupta (2009).** The extractable and the total contents of lead (Pb) in soil and water samples were estimated by atomic absorption spectrophotometer 210VGP.

Plant Analysis:

Lettuce and cabbage plants were analyzed. Plants were rinsed thoroughly with tap then distilled water, dried at 70 ºC for 72h, crushed and digested using an acid mixture of concentrated H2SO4 / HClO4 **(Grimshaw, 1987).**

Parameters*:*

1 –Bioaccumulation factor (BAF) is the ratio between the concentration of heavy metal in the aerial plant part (mg kg $^{-1}$) and its total content in soil (mg kg^{-1}) **(Uchida *et al*. 2007; Xu *et al*., 2024).**

2 –Biological concentration factor (BCF) is the ratio between metal content in plant root and metal content in soil (**Xu *et al*. 2024).**

3 –Translocation factor (TS) is the ratio between the content of heavy metal in the investigated aerial plant part and its corresponding content in root **(Abbas and Abdelhafez, 2013).**

4 –Daily intake of metal (DIM) is calculated according to **Balkhair and Ashraf (2016)** as follows;

DIM= (C metal * C factor * D intake) / B weight

Whereas C metal is metal concentration in food crop, C factor is 0.085 used for the conversion of fresh weight vegetables to dry weight. D intake is 0.527 kg person^{-1} day^{-1} which expresses the average daily intake of food by person and B weight is the average of adult body weight (55.5 kg).

5 –Health risk index (HRI) refers to the ratio between DIM and RfD whereas DIM is the daily intake of metals and RfD is the oral reference dose mg kg^{-1} day^{-1} (EPA, 2002). If the value of HRI >1 for any metal this refers to the food consumer faces a health risk **(Balkhair and Ashraf, 2016).**

Results and Discussion

The main source of contamination with lead in the studied locations was irrigation with waste water (mixture of sewage and industrial waste water) for several years, the chemical analysis of this water was EC = 0.91 dSm^{-1}, pH= 6.25 and Pb content = 8.19 mgL^{-1}.

Lead content in Soil:

Regarding lead content (mgkg$^{-1)}$ in soil; results in Fig.1 and 2 show soil content of total and DTPA-extractable lead (Pb). Total lead content ranged from 62.7 to 346.3 mg kg^{-1soil} which does not exceed the cleaning up level of polluted soils with lead which is 530 mg Kg^{-1} according to the Dutch permissible limits of soil pollution with heavy metals, while the Japanese cleaning up level is 400 mgkg-1and the German one is 500 mgkg^{-1} **(Chen *et al.*, 1999; Kabata-Pendias, 1995).** On the other hand; these concentrations exceed the acceptable limits according to the UK, Austria and Poland levels which is 100 mgkg^{-1} and the Canadian level of 200 mgkg^{-1} **(Kabata-Pendias, 1995).**

Results in Fig. 1 reveal that the total Pb decreased with depth. This may be due to the continuous irrigation with contaminated water in addition to the low mobility of lead through the soil layers.

Figure 2 exhibits the results of extractable-Pb; location 5 shows the highest values of Pb content compared with the other locations. The studied locations show a gradually systematic decrease in Pb content associated with the increase in soil depth, the first layer (0-10cm) contains the highest content of lead followed by the other layers due to the continuous irrigation with waste water. Also the difference between top soil and sub soil in Pb concentration maybe attributed to Pb mobilization through soil horizons which is very low but acidity and formation of Pb – organo complexes play a vital role in increasing Pb solubility and mobilization **(Kabata-Pendias and Sadurski, 2004).** This is shown in Fig. 3 that describe the corresponding content of organic matter in the same soil layers. Organic matter regulates lead mobility and availability in soil **(Liu *et al.*, 2009; Elnajdi *et al.*, 2023).** This may explain the increases in extracted-Pb particularly in locations 4 and 5 (Fig. 2) due to contents of organic matter (Fig. 3). The ability of organic matter in mobilizing metals relays on the nature of the organic matter, soil pH, redox in addition to competing ions and ligands **(Elnajdi *et al.*, 2023).** Increasing soluble organic matter and pb solubility was associated with pH value particularly when reached 7 **(Sauve *et al.*, 1998).** Regarding the electrical conductivity of soil; all the studied locations are non- saline (EC<4 dSm^{-1}).

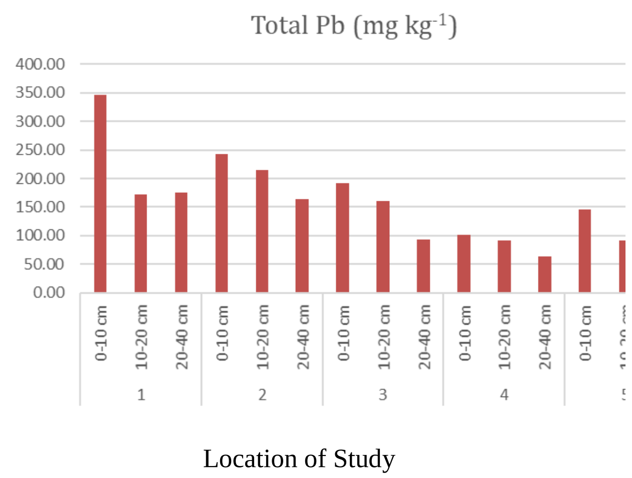

Fig.1 Soil total Pb (mgkg^{-1})

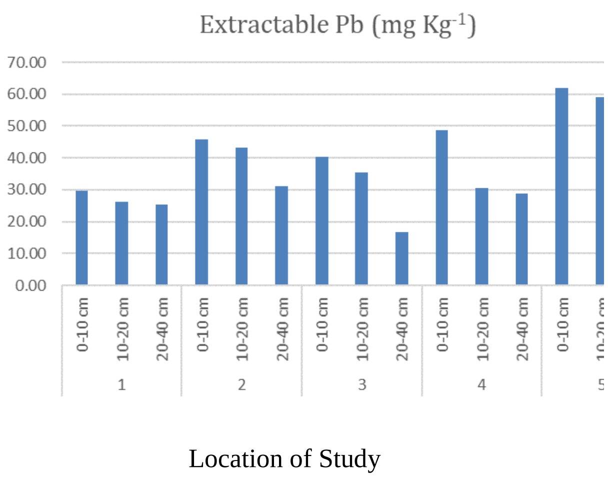

Fig.2 Soil DTPA-Extractable Pb (mgkg^{-1})

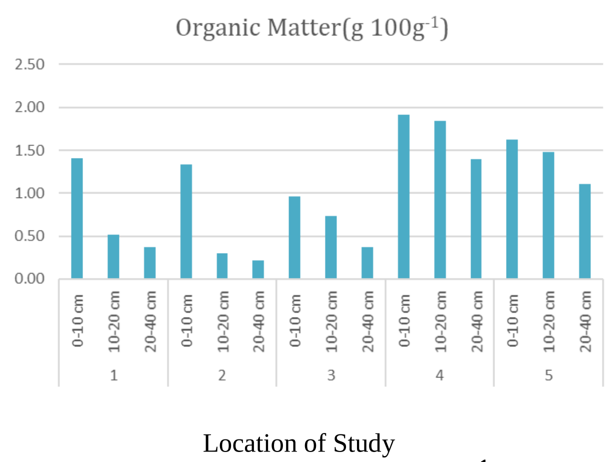

Fig.3 Soil organic matter (g 100g^{-1})

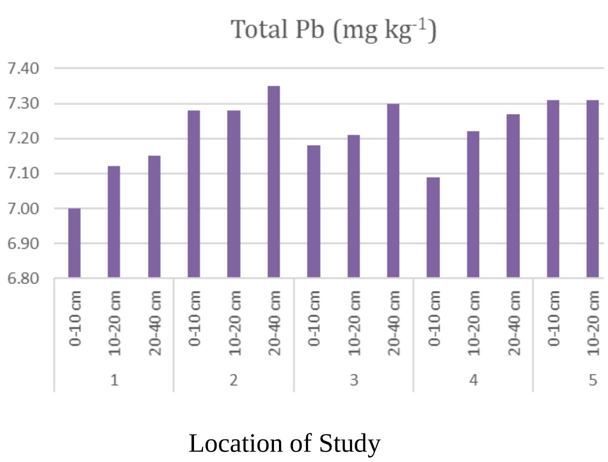

Fig.4 Soil pH (1:2.5 S:W)

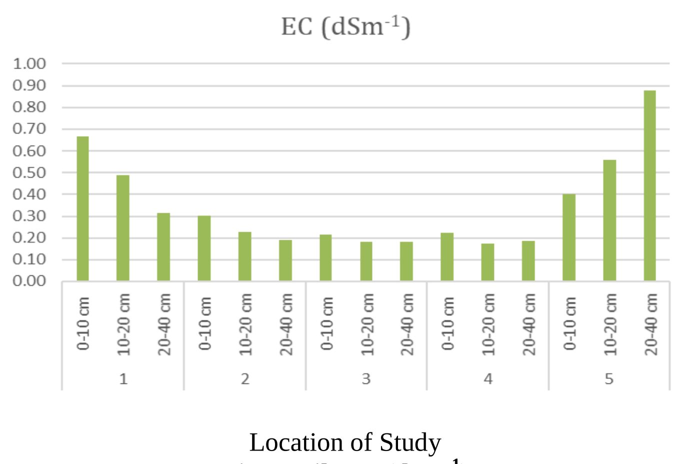

Fig.5 Soil E C (dSm^{-1})

Lead content in plant:

Figure 6 shows that concentrations of lead in the edible parts of cabbage and lettuce plants were higher than the maximum level of lead in leafy vegetables which is 0.1 mgkg^{-1} This means that lead content in eidble parts exceed the permissible level (IADSA, 1995). Thus, cabbage and lettuce plants can accumulate high contents of Pb in plant without toxicity **(Hashim *et al.*, 2017)**. Increase in lead content in different parts of plant were associated with the extractable lead in soil **(Hashim *et al.*, 2017).** This explains high lead in cabbage of location 5 compared with location4. The calculated parameters in cabbage and lettuce were extremely low indicating that they are excluder plants not accumulating lead **(Hashim *et al.*, 2017).** Also translocation factor which explain the plant ability in transferring the heavy metal from root to shoot, Fig. 8 shows that TF values did not exceed 1 therefore lead accumulated in plant roots and stabilized ions of lead in roots with a very low rate of translocation to shoots .Concerning the values related to the health risk assessment (Fig. 9) which are very low .This indicates that concentrations of Pb did not exceed the hazardous limit on human health; but shows that the critical implication of Pb on human health does not appear suddenly after exposure to low concentration.

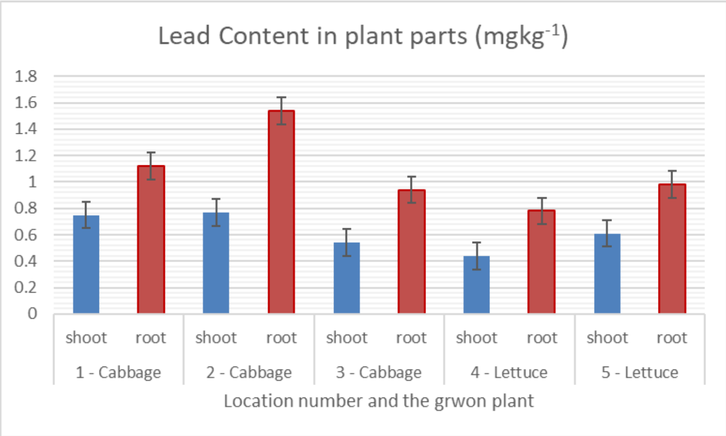

Fig.6 lead content in different parts of the studied plants (mgkg^{-1})

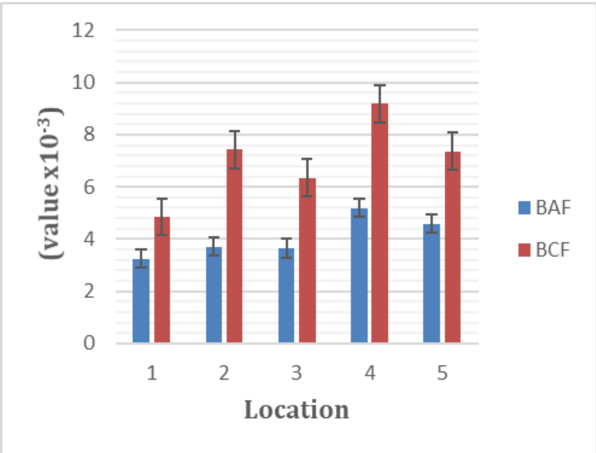

Fig.7 Values of BAF and BCF

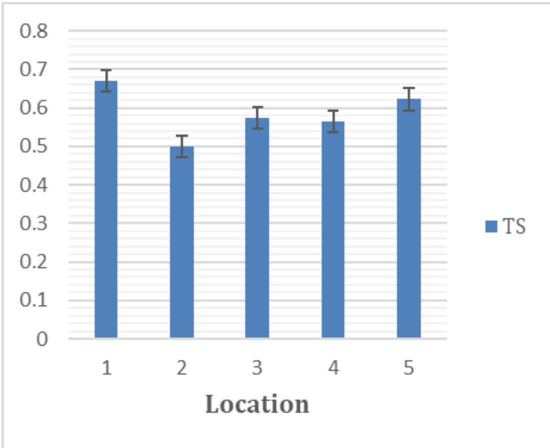

Fig.8 Values of TF

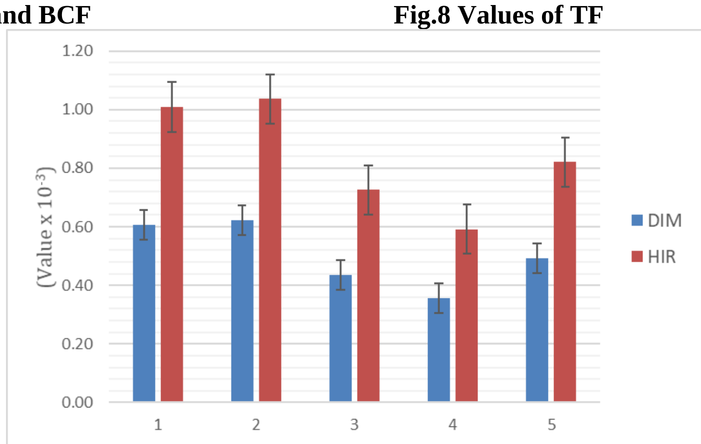

Fig.9 Values of DIM and HIR

Conclusion

The continuous irrigation with industrial waste water increases soil content of heavy metals. Although the low mobility of heavy metals through the soil profile, the agricultural practices particularly plowing could be the main reason of transferring contaminants to the subsurface layers of the soil. These contaminants are absorbed and accumulated in plant parts at different concentration depends on plant variety. Cabbage and lettuce are considered excluder plants. The concentrations of lead in their edible parts plants were higher than the maximum level of lead in leafy vegetables which expose human health to severe risk.

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