Asia Pacific Environmental and Occupational Health Journal (ISSN 2462 -2214), Vol 5 (1): 12 - 18, 2019
Published Online © 2019 Environmental and Occupational Health Society

HEAVY METAL CONCENTRATION IN SOIL OF VEGETABLE CROPS IN PASIR PUTEH, KELANTAN

Siti Marwanis Anua[1]*, Nur Fatien Muhamad Salleh[1], Nurul Izzah Abdul Samad[1], Nurasmat Mohd Shukri[2], Mohd Noor Mamat[1], Nurul Ainun Hamzah[1], Juskasmini Jusoh[1], Md Khairul Azuan Che Azid[1], Wan Mohd Sahnusi Wan Alias[2]

[1]*Environmental and Occupational Health Programme, School of Health Sciences, Health Campus, Universiti Sains Malaysia, 16150 Kubang Kerian, Kelantan, Malaysia.*
[2] *Forensic Science Programme, School of Health Sciences, Health Campus, Universiti Sains Malaysia, 16150 Kubang Kerian, Kelantan, Malaysia.*

Corresponding author: Siti Marwanis Anua; smarwanis@usm.my; School of Health Sciences, Health Campus Universiti Sains Malaysia, 16150 Kubang Kerian, Kelantan, Malaysia

ABSTRACT

Objective: The aim of this study was to determine the concentration of heavy metals such as cadmium (Cd), copper (Cu), chromium (Cr) iron (Fe) and lead (Pb) in soil of vegetable crops (cucumber, corn, ladies' fingers, luffa and water spinach). **Method**: Utilising systematic grid sampling, 48 soil samples were collected from twelve vegetable sites; each site comprised of four soil samples homogenised from a composite sample of three sub points. Soil was collected at the depth of 20 cm using soil corer and undergone drying, acid digestion extraction process and were analysed using Atomic Absorption Spectroscopy. Data obtained was analysed using Statistical Package for the Social Science (SPSS) version 24 at significant level of $p < 0.05$. **Result:** The overall mean concentration of heavy metal in soil measured in descending order was Fe (41.519 mg/L) > Pb (0.575 mg/L) > Cr (0.377 mg/L) > Cu (0.166 mg/L) > Cd (0.027 mg/L). Concentration of Fe was statistically different among the different vegetable (p=0.019). There were significantly lower concentrations of Fe in soil of corn versus cucumber (p=0.018), ladies' fingers (p=0.004) and luffa (p=0.017). **Conclusion**: However, the range of heavy metal concentrations in soil were lower than the allowable limit indicating that the soil was not polluted by these heavy metals.

Keywords: soil, vegetable crop, heavy metal

1. Introduction

Pollution of heavy metals has become one of the biggest problems nowadays, attributable by rapid development of industrialisation and urbanisation. Soil pollution has become a common concern because besides anthropogenic activities, heavy metals may also be produced from natural processes (Arao et al., 2010). Soil pollution occurring from anthropogenic activities might be due to poor agricultural practices such as usage of chemical fertilisers and herbicides as well as due to domestic activities which can lead to poor management of municipal wastes. The risk of food contamination is a great concern as a result of the heavy metal uptakes through root-soil interaction (Nazir et al., 2015; Abdul-Satar et al., 2017; Yang et al., 2018). Metals contamination in agricultural soil will pose as a potential threat to the yielded crops and ultimately consumed by the local community. As a matter of fact, quality of the soil indirectly will determine the heavy metal contents of a crop owing to the food chain cycle. Such proportional relationship between heavy metal concentration in soil and the uptake of heavy metals by plants usually depend on the soil type, plant growth stages and plant species (Afzal et al., 2013) as well as irrigation factor such as utilising waste water contaminated with heavy metals (Abbas et al., 2014).

Accumulation of heavy metals can reduce soil quality, crop yield and the quality of agricultural products (Nagajyoti et al., 2010). Excessive concentration of heavy metal contamination in the soil may cause risks and hazards to humans' health and the ecosystem. As these contaminants may enter the crops from polluted soil, water and air, and therefore causing food contamination that will impact the health of human and animal (He et al., 2015). Given that heavy metals are relatively everywhere thus it can impair human health directly and indirectly. For examples, direct contact with contaminated soil which inadvertently being ingested via contaminated hands, through drinking of contaminated ground water or direct ingestion via the food chain such as soil-plant-human or soil-plant-animal-human routes (Wuana & Okieiman, 2011). Unfortunately, there is no well-established mechanism to eliminate them from the body. Thus, this study aims to determine the concentration level of heavy metals such as cadmium (Cd), copper (Cu), chromium (Cr) iron (Fe) and lead (Pb) in soil of vegetable crops with a view to recommend control measures to reduce the concentration of heavy metals if their presence are above the safe limit. In which elevated heavy metal level might be contributed by widespread usage of pesticides and fertilisers.

2. Materials and Method

2.1. Study area

This study was conducted in November 2018, measuring the concentration of heavy metals (Cd, Cu, Cr, Fe, Pb) in soils of vegetable crops at a rural agricultural area in Pasir Puteh, Kelantan. The study area was chosen because agricultural was one of the residents' main activities. The agricultural area span to 28 acres with chilly as their common yield. The farmers utilised crop rotation method hence they grow other types of vegetables such as cucumbers, corns, ladies' fingers and luffa during the transition phase. The sampling sites were selected based on judgmental sampling to include all crops available during the sampling period. The permission in collecting the soil samples were asked from the management and farmers, together with interview gathering information on types of yields, types of soil, usage of pesticides and fertilisers.

2.2. Soil sampling

A total of 48 soil samples from twelve sampling sites involving five types of vegetable crops namely cucumber, corn, ladies' fingers, luffa and water spinach were collected. The soil samples were collected at the depth of 20 cm from the surface using a pre-cleaned soil corer at four points utilising systematic grid sampling. Three sub-samples were taken at each point that were homogenised into one composite sample. Within the area of 100 m^2 (10 m x 10 m), the four points were chosen at the same gap distance of two meter (starting point starts at 2.0, 4.0, 6.0 and 8.0 m). At each selected point, the three sub-points were determined at one line within the 7.5m length (gap distance were 1.0, 4.25 and 7.5m) (Figure 1). Approximately 2 inches of soil sample was collected and placed into individual polyethylene bag. Each sample was recorded, labelled and transported in a cooler box to the laboratory. All samples were oven-dried for three days (50℃) to remove excess moisture.

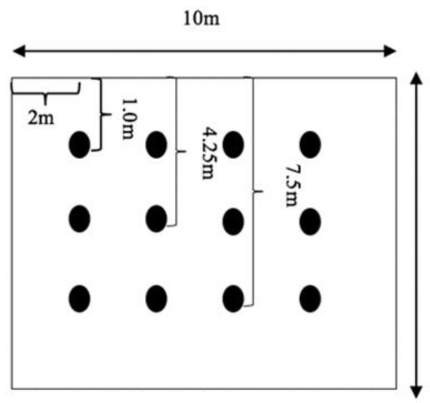

Figure 1. Point of sampling

2.3. Soil acid digestion

The dried soil samples were mashed up using pestle and mortar then were passed through a 2 mm sieve to remove granulometric fraction and any other unwanted materials such as plastics, leaves and rocks. Using analytical balance, 2 g of homogenous soil sample was weighed into 100 ml beaker. The soil acid digestion process was conducted in a fume hood whereby 60% of concentrated HCl and HNO_3 were mixed into the soil sample and was slowly heated until refluxing. After a series of slow heating, refluxing and stirring occasionally, all the digested samples solution was filtered through Whatman filter paper into a 50 volumetric flask and then the volume was diluted with 50 ml of deionised water. Each flask was inverted for at least 13 times to mix and then was transferred into the screw-capped polyethylene bottles. The polyethylene bottles were kept in 5°C until further analysis using Atomic Absorption Spectroscopy (AAS).

2.4. Soil sample analysis

AAS was used to determine the Pb, Cu, Cd, Fe, Cr concentration in acid digestion extraction of soil samples. Prior to that, as quality control and quality assurance, the standard solution for each heavy metal were prepared by serial dilution from reagent grade chemicals following manufacturer's instruction. Deionised water was used as blank solution. Calibration standard solutions were prepared in 50 ml volumetric flasks by using molarity standard equation, M1V1=M2V2, where M was the concentration of stock standard solution while V was the volume of stock standard solution. The calibration graph curve was generated for each calibration standard solution of heavy metal, then were followed by each acid digestion extraction of soil samples to obtain the reading.

2.5. Data analysis

The Statistical Package for the Social Science (SPSS) version 24 was used for data analysis, at significance level of $p<0.05$. As the data obtained was not normally distributed, descriptive results were presented in median and interquartile range whereas value of non-detected was replaced by ½ of limit of detection (Helsel, 2010). The heavy metal concentration in soil between sampling sites and vegetable sites were compared by Kruskal Wallis and Mann-Whitney tests.

3. Results

3.1. Concentration of heavy metals in soils at the sampling sites

The concentration level of Cd, Cu, Cr, Fe and Pb at all sampling site are shown in Table 1. Overall, for total sample, Fe has the highest mean concentration (41.519 mg/L) > Pb (0.575 mg/L) > Cr (0.377 mg/L) > Cu (0.166 mg/L) > Cd (0.027 mg/L).

Table 2 shows the highest median concentration of Cd and Cr were measured in soil collected from ladies' fingers crop C (sampling site 9). Whereas, water spinach crop has the highest level of Cu (0.205 mg/L) compared to other sites. Half of the sampling sites reported non-detected for Pb, the highest level (1.355 mg/L) measured at sampling site 10 (luffa crop A). Except for Cd, all four heavy metals concentration in soil were significantly different between the vegetable sites ($p<0.05$).

Table 1: Concentration level of heavy metals at all sampling sites

Heavy metal	n	Concentration level (mg/L)			
		Mean±SD	**Median (IQR)**	**Minimum**	**Maximum**
Cd	48	0.027±0.023	0.021 (0.004-0.053)	0.004	0.066
Cu	48	0.166±0.123	0.153 (0.129-0.184)	0.041	0.940
Cr	48	0.377±0.268	0.259 (0.133-0.184)	0.081	0.794
Fe	48	41.519±12.371	44.935 (43.808-46.083)	0.325	48.580
Pb	48	0.575±0.597	0.231 (0.008-1.190)	0.008	1.486

Table 2. Median concentration of heavy metals in soils of vegetable crops at the sampling sites

Site	Vegetable Site	Median (IQR) (mg/L)				
		Cd	Cu	Cr	Fe	Pb
1	Cucumber A	*0.004#*	0.157 (0.106-0.745)	0.193 (0.189-0.212)	44.925 (44.723-45.502)	1.240 (1.178-1.437)
2	Cucumber B	0.020 (0.017-0.022)	0.169 (0.128-0.210)	0.366 (0.315-0.397)	43.510 (42.320-44.453)	*0.008#*
3	Cucumber C	0.059 (0.058-0.060)	0.123 (0.116-0.129)	0.756 (0.738-0.782)	47.755 (47.478 -48.205)	*0.008#*
4	Corn A	0.004 (0.004-0.021)	0.127 (0.109-0.157)	0.145 (0.110-0.156)	44.590 (43.695-44.855)	1.127 (0.959-1.276)
5	Corn B	0.008 (0.004-0.019)	0.183 (0.144-0.219)	0.100 (0.098-0.107)	1.120 (0.431-2.625)	0.899 (0.737-1.046)
6	Corn C	0.053 (0.052-0.056)	0.140 (0.133-0.164)	0.596 (0.572-0.628)	44.370 (39.008-46.305)	*0.008#*
7	Ladies' Fingers A	0.004 (0.004-0.015)	0.185 (0.093-0.260)	0.134 (0.116-0.151)	46.005 (45.028-46.255)	1.307 (1.18-1.346)
8	Ladies' Fingers B	0.012 (0.004-0.022)	0.144 (0.109-0.179)	0.127 (0.905-0.137)	44.860 (42.435-45.035)	1.040 (0.582-1.167)
9	Ladies' Fingers C	0.064 (0.059-0.066)	0.149 (0.142-0.179)	0.777 (0.731-0.793)	47.670 (46.583-48.360)	*0.008#*
10	Luffa A	0.005 (0.004-0.013)	0.054 (0.041-0.140)	0.130 (0.119-0.136)	44.990 (44.668-45.433)	1.355 (1.308-1.375)
11	Luffa B	0.053 (0.051-0.055)	0.156 (0.146-0.157)	0.714 (0.685-0.765)	45.665 (44.390-45.860)	*0.008#*
12	Water Spinach	0.031 (0.027-0.036)	0.205 (0.175-0.222)	0.506 (0.449-0.542)	45.520 (43.585-46.488)	*0.008#*
	p value	0.080	0.001*	0.001*	0.001*	0.001*

**Significant different at $p<0.05$; Statistical test – Kruskal Wallis, #value non-detected was replaced by ½ of Limit of Detection, IQR - Interquartile Range, Cd – Cadmium, Cu – Copper, Cr – Chromium, Fe- Iron, Pb - Lead*

3.2. Concentration of heavy metal in soils based on types of vegetables crop

Table 3 categorised the soils collected from sampling sites based on the types of vegetable grown (cucumber, corn, ladies' fingers, luffa and water spinach) irrespective of the sites of sampling. There was a significant different in the concentration of Fe between the types of vegetable (p=0.019), with the lowest Fe level was measured in soil grown with corns (Median: 43.380 mg/L, IQR: 1.875-44.855 mg/L), and the highest was at ladies' fingers' (Median: 46.005 mg/L, IQR: 44.825-47.303 mg/L). None of all other heavy metals in soils were found to be statistically different between the types of vegetable grown (p>0.05).

In order to further compare the concentration of heavy metal in soils between corn (lowest concentration) and each type of vegetable crops, we used Mann-Whitney test (results were not tabulated). There were significantly lower concentrations of Fe in corn soil versus cucumber (p=0.018), ladies' fingers (p=0.004) and luffa (p=0.017). A significantly higher median concentration of Cr was found in cucumber soil (0.366 mg/L) compared to corn soil (0.146 mg/L), p=0.021. Whereas, for Cu concentration, the median difference was statistically significant between corn (0.140 mg/L) and water spinach (0.205 mg/L) only, p=0.039.

Table 3. Comparison of heavy metal concentrations in soils between types of vegetable crops

Vegetable Site	n	Median (IQR) (mg/L)				
		Cd	**Cu**	**Cr**	**Fe**	**Pb**
Cucumber	12	0.019 (0.004-0.058)	0.141 (0.117-0.179)	0.366 (0.200-0.741)	44.925 (43.970-47.633)	0.008 (0.008-1.187)
Corn	12	0.017 (0.004-0.052)	0.140 (0.132-0.177)	0.146 (0.099-0.588)	43.380 (1.875-44.855)	0.843 (0.008-1.054)
Ladies' Fingers	12	0.019 (0.004-0.061)	0.148 (0.132-0.187)	0.141 (0.120-0.754)	46.005 (44.825-47.303)	1.040 (0.008-1.251)
Luffa	8	0.033 (0.004-0.053)	0.149 (0.048-0.157)	0.408 (0.129-0.718)	45.375 (44.668-45.733)	0.650 (0.008-1.357)
Water Spinach	4	0.031 (0.027-0.036)	0.205 (0.175-0.222)	0.506 (0.449-0.542)	45.520 (43.585-46.488)	*0.008#*
p value		0.876	0.117	0.178	0.019*	0.240

**Significant different at p<0.05; Statistical test – Kruskal Wallis, #value non-detected was replaced by ½ of Limit of Detection, IQR - Interquartile Range, Cd – Cadmium, Cu – Copper, Cr – Chromium, Fe- Iron, Pb - Lead*

4. Discussion

From the result, it can be summarised that the overall agricultural area is still in a safe level, and did not exceed allowable limit when compared to the United States Environmental Protection Agency's (US EPA) levels for soil contamination (USEPA, 2002) and maximum allowable level regulated by the Environment Protecting Administration of China (EPAC, 1995). Fe was found to be the most predominant at the soil sampling sites in which the occurrence is rarely affected by anthropogenic factors (Abdel-Satar et al., 2017). Based on our interview and observation, the low levels of heavy metal concentrations may be due to the fact that the farmers at the vegetable farms had minimised the usage of chemical-based pesticide in managing their crops. It has been well established that usage of pesticides and fertilisers can increase the level of heavy metals in soils (He et al, 2005; Wuana & Okieimen, 2011; Haliza & Farah Adhila, 2015). This might as well be the case for the sampling site 5 of corn crop B, which recorded the lowest median concentration of Fe in soil (1.120 mg/L) compared to other sites. It was statistically significant when compared to cucumber, ladies' fingers and luffa ($p<0.05$). The farmer at site 5 used organic fertiliser despite its high cost. It has been well documented that organic agricultural production not only ensures better food quality but also helps maintaining soil fertility (Karak et al., 2017). However, it is recommended to have at least 10 mg/kg of iron because it is considered as micronutrient and essential in the formation of chlorophyll and photosynthesis process (Cantisano, 2000; Westfall & Bauder, 2014). Iron deficiency in soil may be due to low pH level which cause the soil to become acidic or it can happen to the area which frequently have had the topsoil removed by leveling or erosion. Further recommendation will be proposed to the land owner to rectify the situation.

In contrast to our findings, higher level of Cu and Pb were found in soils at vegetable areas in Kota Bharu, Kelantan (Haliza & Farah Adhila, 2015), although their levels were below the standards as proposed by various agencies. They explained that the below than safe level was might be due to the farmers at Kota Bharu vegetable areas utilised biological controls such as dragonflies to overcome fruit flies attacking the plants. They also controlled the pests physically and mechanically by using the insect's traps such as lights and stickers, instead of relying to the conventional method of pest control. Meanwhile in this study, the Cu concentration was significantly higher in water spinach soil compared to corn soil. Research shows that most Cu introduced into the environment will rapidly become stable and results in a form which does not pose a risk to the environment (Wuana & Okieimen, 2011). It has also been documented that water spinach able to tolerate high heavy metal uptakes or toxicity (Awangku Nabil Syafiq, 2009) however, fortunately it is not magnified in the body or bioaccumulated in the food chain (Wuana & Okieimen, 2011). Meanwhile Cr level was shown to be significantly different in the soils measured between corn and cucumber. Cr concentration largely depends on the characteristic of the soil, including the content of clay and iron oxide and the amount of organic matter present (Wuana & Okieimen, 2011). The study location has a clay type of soil and as an agricultural area which crop rotation method was practiced, the soil characteristic might be different. However, it must be noted that Cr level was at a safe level.

The toxic heavy metals may persist in the environment thus lead to geo-accumulation, bioaccumulation and biomagnifications (Sahibin et al., 2008; Singare et al., 2012). This assessment on soil pollution is important for both agricultural and non-agricultural areas, since the persistence characteristic of the heavy metal itself which causes them to be the risk factor for environment.

5. Conclusion

Fourty-eight soil samples were collected and analysed for Cd Cu, Cr, Fe and Pb from an agricultural farm in Pasir Puteh Kelantan. The range of heavy metal concentrations in soil were lower than the allowable limit which means that the soil is not polluted by these heavy metals.

Acknowledgement

The authors would like to thank Universiti Sains Malaysia, School of Health Sciences, Mr. Muhammad Zulfadlil Azhim Hj. Ayub, Mr. Wan Isamuddin Wan Othman and the Desa Alam Shah residents. Not to forget, our special thanks and gratitude to the Environmental and Occupational Health students involving 34 third year (KPP Batch 9) and 28 second year (KPP Batch 10) students who had conducted the soil sampling and analysis as part of their teaching and learning for the core course GTK310 Measurement and Monitoring of Contaminants and GTK202 Pollution and Health, respectively, during the semester 1 Academic Session 2018/2019.

References

Abbas, N., Deeba, F., Jamil, N., Chaudhary, M. N., Khan, R. A. (2014). Comparative study of metal contents in soil and plants being irrigated by tannery and fresh water. *Asian Journal of Chemistry*, 26(4), 963-966.

Abdel-Satar A.M., Al-Khabbas M.H., Alahmad W.R., Yousef W.M., Alsomadi R.H., Iqbal T. (2017). Quality assessment of groundwater and agricultural soil in Hail region, Saudi Arabia. *Egyptian Journal of Aquatic Research*, 43, 55-64.

Afzal, S., Abdul, N., Nazeef, U., Ali, R., Muhammad, A., Muhammad, Z., Muhammad Suleman, K. (2013). Comparative study of heavy metals in soil and selected medicinal plants, *Journal of Chemistry*, Article ID 621265, 5 pages.

Arao T., Ishikawa S., Murakami M., Abe K., Maejima Y., Makino T. (2010). Heavy metal contamination of agricultural soil and countermeasures in Japan. *Paddy and Water Environment*, 8(3), 247-257.

Awangku Nabil Syafiq, A. M. (2009). Uptake of heavy metals by water spinach from sludge amended soils. B.Sc Dissertation, Universiti Malaysia Sarawak.

Cantisano A. (2000). Know your soil, a handbook for organic growers and gardeners in temperate and sub-tropical regions. Organic Ag Advisors, Colfax, CA, Edited and adopted by Julian Dumanski, RDV, World Bank.

Environmental Protecting Administration of China, EPAC, GB 15618-1995 (1995). *Environment quality standard for soils*. Environmental Protecting Administration of China, Beijing, China.

He, Z., Shentu, J., Yang, X. Baligar, V.C., Zhang, T. & Stofella, P.J. 2015. Heavy metal contamination o soils: Sources, indicators and assessment. *Journal of Environmental Indicators,* 9, 17-18.

Helsel, D. (2010). Much ado about next to nothing: incorporating nondetects in science. *Annals of Occupational Hygiene,* 54 (3), 257-262

Karak, T., Bora, K., Paul, R. K., Das, S., Khare, P., Dutta, A. K., Boruah, R. K. (2017). Paradigm shift of contamination risk of six heavy metals in tea (*Camellia sinensis L.*) growing soil: A new approach influenced by inorganic and organic amendments. *Journal of Hazardous Materials*, 338, 250-264.

Nagajyoti, P. C., Lee, K. D., & Sreekanth, T. V. M. (2010). Heavy metals, occurrence and toxicity for plants: a review. *Environmental Chemistry*

Letters, 8(3), 199–216. doi:10.1007/s10311-010-0297-8

Nazir, R., Khan, M., Masab, M., Rahman, H., Rauf, N., Shahab, S., Ameer, N., Sajed, M., Ullah, M., Rafeeq, M., and Shaheen, Z. Accumulation of heavy metals (Ni, Cu, Cd, Cr, Pb, Zn, Fe) in the soil, water and plants and analysis of physico-chemical parameters of soil and water collected from Tanda Dam kohat. (2015). *Journal of Pharmaceutical Sciences and Research*, 7(3), 89-97.

Sahibin, A.R., Muhd Barzani, G., Mohd Nizam, M.S., Wan, M.R.I., Azman, H., Sharilnizam, Y., Maniyana, J. (2008). Kandungan logam berat di dalam beberapa siri tanah oksisol di sekitar Tasik Chini, Pahang. *The Malaysian Journal of Analytical Sciences*, 12(1), 95-104.

Singare, P. U., Trivedi, M. P., Mishra, R. M. (2012). Sediment heavy metal contaminants in Vasai Creek of Mumbai: pollution impacts. *American Journal of Chemistry*, 2(3), 171-180

USEPA. (2002). United States Environmental Protection Agency. Supplemental guidance for developing soil screening levels for superfund sites. Office of Solid Waste and Emergency Response, Washington D.C. http://www.epa.gov/superfund/health/conmedia/soil/index.htm

Westfall, D.G. & Bauder, T.A. (2014). Zinc and iron deficiencies, No. 0545. Colorado State University.

Wuana R.A. & Okieimen F.E. (2011). Heavy metals in contaminated soils: A review of soil chemistry, risks and best available strategies for remediation. ISRN Ecology, vol. 2011, Article ID 402647.

Yang J., Ma S., Zhou J., Song Y., Li F. (2018). Heavy metal contamination in soils and vegetables and health risk assessment on inhabitants in Daye, China. *Journal of International Medical Research*, 46(8), 3374-3387.