ASSESSMENT OF HEAVY METALS IN DIFFERENT PLANTS SPECIES AROUND MEHMOOD BOOTI DUMPING SITE AND ASSOCIATED HUMAN HEALTH RISK

S. Ashraf[1*]

[1]College of Earth and Environmental Sciences, Quaid-e-Azam Campus, University of the Punjab, Lahore 54590, Pakistan; sana.cees@pu.edu.pk
[*]Correspondence email address: sana.cees@pu.edu.pk

ABSTRACT: Prolific release of heavy metals in the environment is causing various environmental and human health risk. Therefore, the present study was planned to study the level of heavy metals in various part of plants growing around a dumping site of Lahore. A total of eightmetals (Cd, Cr, Ni, Fe, Cu, Pb,Zn,Mn) were examined in wild and edible plants around Mahmood booti dumping site. A total of nine food crops, six wild herbs and three wild shrubs were screened for heavy metals. Ni, Cu, Pb and Cd went recorded beyond the permissible of World health organization (WHO) in these plant species. The Accumulation factor (AF) is > 1 for all eight metals except Mn and Cu in most of the studied food crops. Human Health risk index HRI >1 was also recorded for Cd in *Spinacia Oleracea* and*Solanamtubersum*. We concluded that elevated level of heavy metals around dumping sites is posing some serious health risk which should be mitigated effectively to avoid future worst consequences.

Key words: Metals; Food crops; wild plants; Accumulation factor (AF); Health risk index (HRI).

(Received 01.10.2024 Accepted 03.12.2024)

INTRODUCTION

Speedy industrialization, population explosion and global urbanization have caused solid waste generation. Solid waste includes municipal, industrial and commercial waste and produce an extensive amount of pollutants disturbing environment, vegetation and Human health (Han *et al.*, 2014). Municipal solid waste landfills often represent a major environmental problem due to their closeness to inhabited areas(Pastor & Hernández, 2012). Solid waste management (SWM) is not proficient in developing countries and cause serious hazard to local environment and Human's health. These developing countries have low financial and human resources (Mensah, 2006).Local authorities not provide proper management for waste collection or waste dumping sites are not sufficient as compared to waste generation (Calo and Parise, 2009).Unlined or unfenced dumping sites and burning of waste are general, and are potential source of pollutants in water, soil and air affecting the people living close to these perilous landfills. Waste decomposes easily under high temperature and considerable amount of leachate and unbearable odour is generated. Soil is the main receiver of waste dump which accumulate organic pollutants, toxic inorganic elements and heavy metals in it and cause injurious effects to vegetation, soil and ultimately to human health.

Presence of high concentration of metals in farmlands around dumpsites is due to leaching and surface runoff. Eventually these metals are up taken by plants resulting in bioaccumulation and transfer through food chain(Opaluwa *et al*., 2012). Plants uptake these metals in form of mobile ions through their root or foliar absorption (Fatoki, 2000).Metal concentration is high in leafy vegetables and medicinal plants. Metal exposure through food chain is mainly because of Plant uptake. Metal compounds cause severe contamination and carcinogenicity in plants, so various translocation and uptake patterns of plants should be studied(Olowoyo *et al*., 2012).Wild plants also affect the human body through their medicinal application. These toxic metals in wild plants may pose severe health hazards to human life. So these wild plants should be checked properly according to their safety and quality (Mehmood *et al*., 2013).

Metalconcentrations, potential health impacts and traditional uses of medicinal and edible crops were studied previously in diverse regions of Pakistan(Aziz *et al*., 2017,Ebrahim *et al*., 2014, Rehman *et al*.,2017). The present study is designed to study different vegetables, cereal crops, grasses and medicinal plants were around the Mehmood booti dumping site to investigate the (1) metal content in medicinal plants and vegetables (2) traditional uses, safety and efficacy of medicinal plants (3) metal accumulation from soil to above soil parts of the vegetable plants (4) potential health risk assessment through vegetable intake in the area.

MATERIAL AND METHODS

Study site: Agricultural area presentin immediate vicinity of Mehmood Booti dumpsite 31º36'15.79"N and 74º23'43.36"E was selected for this study. Crops grown here include vegetables and cereals .i.e. *Triticum aestivum L., Avena sativa L., Brassica acmpestris L., Allium cepa L., Mentha Spicata L., Solanum tuberosum L.,Allium sativum L., Spinacia oleracea L., Corriandrum sativum L.* andcommon wild plants include herbs and shrubs .i.e. *Chenopodium album L.,Parthenium hysterophorus L., Euphorbia helscopia L., Cannabis Sativa L., Spicata L., Achyrenths aspera L., Ricinus cummunis L., Calotropusprocera L., Solanum nigrum L.* Mostly drain wastewater is used for irrigation which receive leachate from dumpsite. The vegetables grown here are consumed by local people or sold in the markets of nearby areas. People also have cows there and sale the milk.

Plant sampling: Sampling was performed in the start of January 2014 and temperature of Lahore was 11 ºC. Specifically the studied vegetables and medicinal plants were located around the main dumpsite. Six wild herbs *Chenopodium album L.,Parthenium hysterophorus L., Euphorbia helscopia L., Cannabis Sativa L., Mentha Spicata L., Achyrenths aspera L.*,.,and 3 wild shrub *Ricinus cummunis L., Calotropusprocera L., Solanum nigrum L.*nine food crops *Triticum aestivum L., Avena sativa L., Brassica acmpestris L., Allium cepa L., Mentha Spicata L., Solanum tuberosum L.,Allium sativum L., Spinacia oleracea L., Corriandrum sativum L.*, were collected in triplicates around the dump site. All plants were labelled and stored in polythene bags and taken to the lab.

Soil Sampling: Fifteen upper soil samples (0-2cm) were gatheredand these soil samples were then air dried, grounded, sieved (2mm mesh) and stored in polythene bags for further examination.

Sample preparation: Above ground parts of the food crops and medicinal useable parts of wild plants were cleaned (with distilled water) to eliminate all dust particles. These plant parts were dried (for 24 h, at 70-80 ºC), grounded, sieved (2mm mesh) and kept in polythene bags at normal room temperature till nextlaboratory investigation.USEPA (2007) method3051 Awas followed for the digestion of soil samples using Microwave Accelerated Reaction System. A representative sample of soil(0.5 g) was taken and digested in 9 ml nitric acid and 3 ml hydrochloric acid at 180 °C for 10 minutes and for 10 minutes holding time. Plants were digested according to USEPA (2007) method3052 A. 0.5 g of plants sample was taken and digested in 9 ml nitric acid and 3 ml hydrochloric acid at 100 °C for 5 minutes and for 10 minutes hold.

Quality control analysis: For sample preparation chemicals were obtained (MERCK chemicals Germany). All samples were analyzed in triplicates. A blank was also prepared and run after every five samples. De-ionized distilled water was used for standard preparation and to wash Glassware after rinsing them with 10% nitric acid.Accuracy and precision of analysis were checked with standard solutions which were prepared by dilution of certified standards with de ionized distilled water (NIST-SRM SRM1570A for plants and SRM 2709 for soil) for corresponding metal ions.

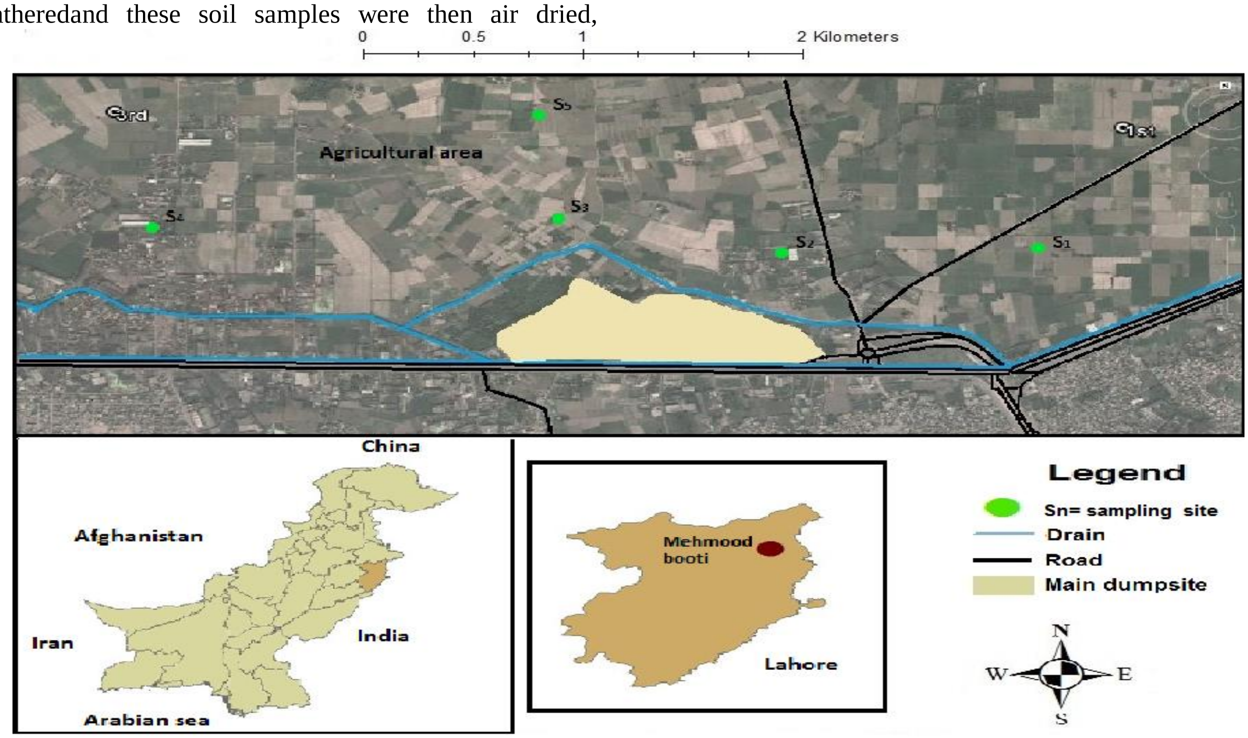


Fig:1. Map of study area showing location of Mehmood dumping site

Translocation factor and Health risk index: Transfer of metals from soil to the plants can be find out by accumulation factor (AF) which is the ratio between metal concentrations in edible parts of food crops to metal concentrations in soil(Khan *et al*., 2013). The accumulation factor (AF) was calculated as:

$$AF = \frac{\text{metal concentration in Food crops edible Parts}}{\text{metal concentration in soil}} \quad (1)$$

Foranalysing the human health risk from food crops local people of Mehmood Booti were questioned for daily intake of food, their age and body weight.Total 70 questionnaires from the local male and female population (14–50 years age group) were examined for health risk surveillance.

Daily intake of metals (DIM) wasfind out through formula given below:

$$DIM = \frac{C_{\text{metal}} \times C_{\text{factor}} \times D_{\text{food intake}}}{B_{\text{average weight}}} \quad (2)$$

Where

C_{metal}= concentration of metals in food crops

C_{factor} = conversion factor

$D_{foodintake}$ = daily intake of food crops

$B_{\text{average weight}}$ = average body weight

Conversion factor (0.085) was followed for conversion of vegetables to dry weight. Average daily intake of food crops was 0.647 kg person^{-1} day^{-1} and the average value for body weight for adult's population was 48.5 kg. By using daily metal intake, Human health Risk Index (HRI) is calculated further.

Health risk index (HRI) was determined(Khan *et al*., 2013) using equation given below:

$$HRI = \frac{DIM}{RfD} \quad (3)$$

Oral reference dose (RfD) is the contact of individuals to contaminants on daily basis which may pose no significant hazard during their lifespan. The RfDs for hazardous metals like Cr, Ni, Mn, Pb and Cd are 1.5E-0, 2E-2, 1.4E-1, 3.5E-3 and 1E-03 mg kg^{-1} d^{-1} respectively[3]. HRI > 1 for toxic metals indicates significant health risk to consumer population.

Statistical analysis: Basic descriptive statistical analysis was applied by using statistical package SPSS (version20). Sampling locations were obtainedwith the use of Arc GIS (version 9.3)

RESULTS AND DISCUSSION

Metal concentrations in soil samples: Concentrations of metals for soil samples are presented in Table 1. Metallevels (mg kg^{-1}) were in order: Fe > Mn > Zn > Cu > Ni > Pb > Cd > Cr with concentration ranges from 2806.17 to 5981.15, 112.67 to163.82, 15.91 to 59.09, 9.57 to 26.8, 6.07 to 11.92, 1.51 to 8.36, 0.79 to 2.11, 0.24 to 0.8 respectively. Irrigation with leachate containing wastewater causes contamination of soil with metals. These metals adhere to the soil particles and are not biodegradable so soils are the eventual sink of metals (Aiman *et al*., 2016). Concentrations of Fe, Pb, Cr, Cu, Ni, Zn and Cd were found higher in Spain, India and Pakistan(Ali *et al*.,2013,Bora *et al*., 2012,Kanmani and Gandhimathi, 2013,Pastor and Hernández, 2012,Rehman *et al*., 2017).

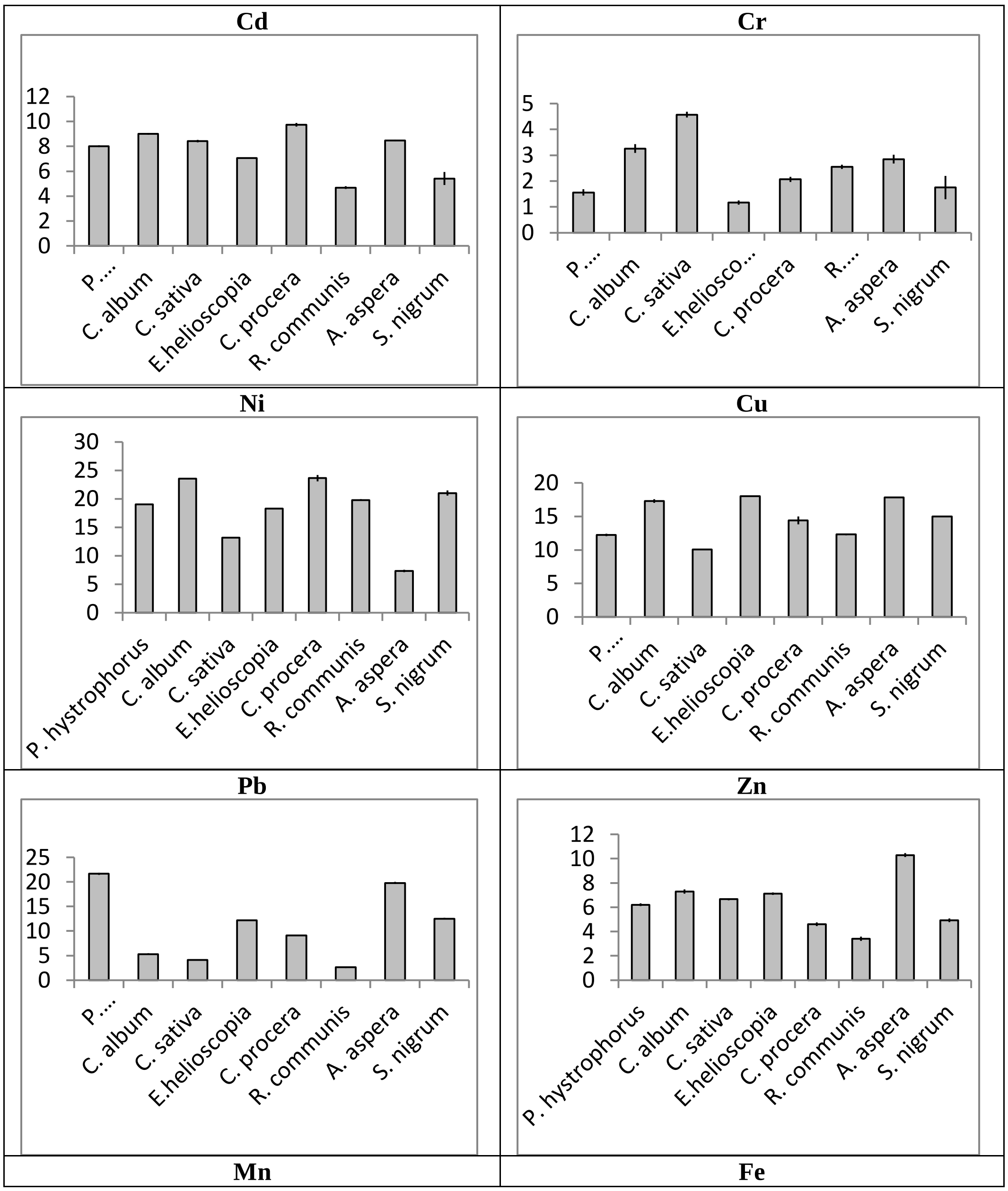
Table 1. Heavy metal concentrations (mg kg^{-1}) of agricultural soil samples around Mehmood Booti dumping site

Metals	Statistics	Concentration (mg/kg)	Metals	Statistics	Concentration (mg/kg)
Cr	**Mean ±SD**	0.58±0.15	**Cu**	**Mean ±SD**	15.52±5.8
	Min-max	0.24-0.8		**Min-max**	9.57-26.8
Ni	**Mean ±SD**	8.97±1.97	**Mn**	**Mean ±SD**	138.44±19.26
	Min-max	6.07-11.92		**Min-max**	112.67-163.82
Zn	**Mean ±SD**	34.69±13.95	**Fe**	**Mean ±SD**	3981.84±1055.78
	Min-max	15.91-59.09		**Min-max**	2806.17-5981.15
Pb	**Mean ±SD**	5.22±2.36	**Cd**	**Mean ±SD**	1.4±0.43
	Min-max	1.51-8.36		**Min-max**	0.79-2.11

Metal concentrations in wild plants: Results of metals investigated in wild plants around the Mehmood Booti dump site are given in fig 4. Concentrations of Cd (4.58-9.88 mg kg^{-1}), Cr (1.09-3.44 mg kg^{-1}), Ni (7.21-23.64 mg kg^{-1}), Fe (295.92-1206.52 mg kg^{-1}), Cu (10.07-18.04 mg kg^{-1}), Mn (14.23-82.92 mg kg^{-1}), Pb (2.44-21.88 mg kg^{-1}) and Zn (3.23-10.43 mg kg^{-1}) were recorded for wild plants. Level of heavy metals reduced as follows: Fe>Mn>Ni>Pb>Cu>Zn>Cd>Cr. *C. sativa* has high concentration of Cr (4.46-4.68 mg kg^{-1}), *E. helioscopia* has high ranges of Fe (1146.37-1206.52 mg kg^{-1}), Cu concentrations are high both in *A. aspera* and *E. helioscopia.*

*C. procera*has high concentrations of Mn (82.67-82.92 mg kg^{-1}). *P. hysterophorus* has high concentrations of Pb (21.45-21.88) and Chenopodium album has high concentrations of Zn (7.11-7.45 mg kg^{-1}). The permissible limits for medicinal plants are 10, 15, 150, 200, 5-30 and 10 mg/g for Ni, Cu, Cr, Zn, Cd and Pb respectively. Ni, Cu and Pb concentration are above the permissible limits. Ni, Pb, Zn and Cr concentrations were found high in *C. album*, *C. procera*, *A. aspera* and *P. hysterophorus* which were found lower than concentration ranges from 2.4 to 46.0 mg $kg^{-1}$for Ni, 0.5 to 39.01 mg kg^{-1} for Pb, 11.4 to 42.2 mg kg^{-1} for Cr and 0.34 to 42.4 mg kg^{-1} for Zn in other areas of Pakistan[24] while Fe in *E. helioscopia* and Cu in *A. aspera* and *R. communis* were found highest than concentrations reported in India 33.701 to 308.467 mg kg^{-1} for Fe and 3.535 to 10.7 mg kg^{-1} for Cu(Rajan *et al*., 2014).

These wild plants have medicinal value and are used for the treatment of various ailments including asthma, bronchitis, intestinal problems, obesity, jaundice, gastric troubles, kidney problems, stone in bladder and kidney etc. These wild plants were also used as laxative, diuretic, narcotics, sedative, tonics and carminative agents. Most frequently used mode of administration was oral followed by topical, external and brush type mode of application. Different plant parts leaves, fruit, flower, branch, root, bark and seed, gum, pod, latex and whole plant were used in preparation of herbal medicines. Leaves, fruits, seeds, roots and tubers are the common parts of plants which are used in preparation of traditional medicines because these parts have large amount of such substances which are biologically active(Rehman *et al*., 2017).



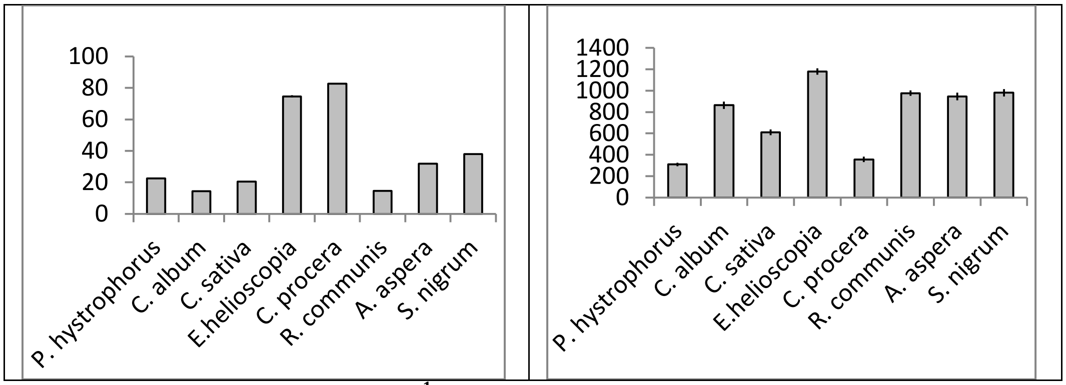
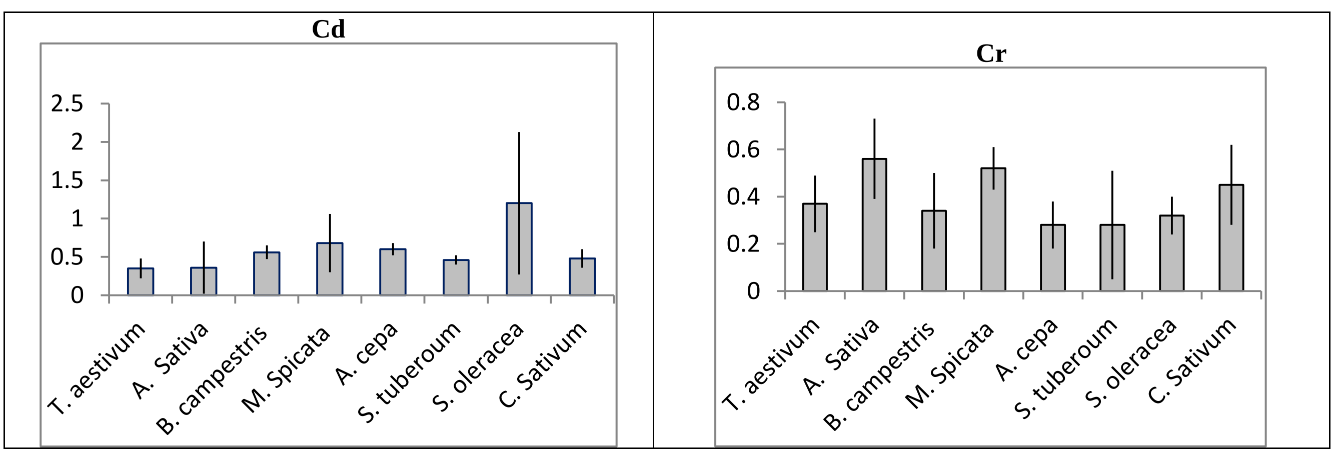


Fig 2. Metalconcentrations (mg kg^{-1}) in wild plants around Mehmood booti dumping site.

Metalconcentrations in vegetables and cereal crops: Basic descriptive statistics for concentrations of eight metals in nine different vegetables and cereal crops were presented in Fig 4. Metal concentrations ranged for Cd from 0.6 to 2.86 mg kg^{-1}, for Cr 0.07 to 0.9 mg kg^{-1}, for Ni 4.08 to 7.64 mg kg^{-1}, for Fe 2.99 to 938.76 mg kg^{-1}, for Cu 0.33 to 10.23 mg kg^{-1}, for Mn 0.11 to 39.40 mg kg^{-1}, for Pb 0.16 to 12.32 mg kg^{-1} and for Zn 0.23 to 24.54 mg kg^{-1}. Overall trend for metal levels appeared as Fe>Mn>Zn>Pb>Cu>Ni>Cd>Cr. Fe concentrations 111.86-938.76 mg kg^{-1} in *Brassica campestris*, Cr 0.42-0.64 mg kg^{-1} in *Mentha spicata*, Ni 5.67-7.64 mg kg^{-1}in *Avena sativa*, Pb 0.98-2.16 mg kg^{-1} in *Corriandrum sativum*, Cd, Cu and Zn concentrations in *Spinacha oleracea* were found highest 0.65-2.86, 9.93-10.23 mg kg^{-1} and 24.13-24.54 mgkg^{-1} respectively.

World Health Organization standard limits for food crops are 2.3, 0.2, 500,5.0 and 67 mg kg^{-1} for Cr, Cd, Mn, Pb and Ni, respectively(WHO/FAO, 2007). Cd level was exceeding the permissible limits in all food crops. In *Corriandrum sativum* Pb concentrations are above the limits. Metal concentration in edible crops is ascribed to variability of metal uptake in plant andsoil type. Metalconcentrations in Greece, China and Pakistan were found higher than our study (Gu *et al*., 2016,Khan *et al*., 2013, Noli and Tsamos, 2016,Olowoyo *et al*., 2012,Olowoyo and Lion, 2013,Rehman *et al*., 2017). Pb and Cd concentrationswere found 1.8 to 11 mg kg^{-1} and 0.12 to 1.6 mgkg^{-1} respectively in KPK Pakistan .In Zhejiang China Pb and Cd levels were recorded lower than current study 0.015 and 0.022 mg kg^{-1}, respectively.

Morphological and physiological alterations in plants play a key role for translocation, accumulation and elimination of metals.Build-up of the metals above permissible limits poses significant health risk to the humans around the dumpsite. Our results indicate that migration of leachate from unfenced dumpsite and irrigation of wastewater result accumulation of toxic metals in edible crops that was crossing the permissible limits of (WHO/FAO, 2007) in most of the food crops.



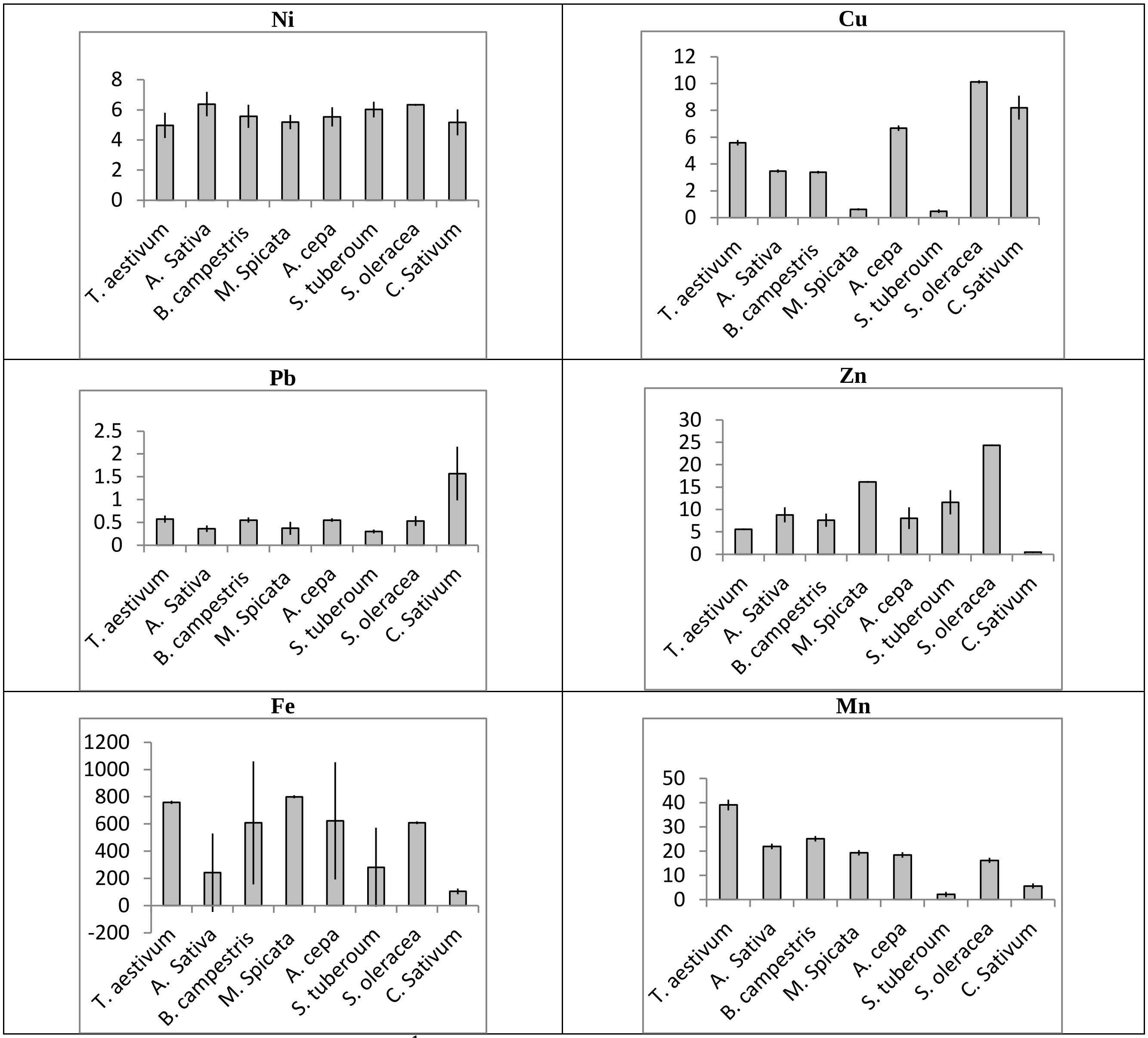


Fig 3. Metal concentrations(mg kg^{-1}) in edible parts of food crops around Mehmood booti dumping site

Metal accumulation from soil to plant: The AF values for edible crops are shown in Tables 2. AF values ranged from 0.05 to 1.71, 0.11 to 1.18, 0.44 to 1.03, 0.02 to 0.94, 0.02 to 1.19, 0.04 to 1.09, and 0.0008 to 0.87 for Cd, Cr, Ni, Cu, Pb, Zn and Mn respectively. AF value for Cr is highest in *S. tuberosum* (0.11-1.55). For Ni AF is highest in *A sativa* (0.50-1.03). *S olearacea*has highest AF for Cu and Cd (0.33-1.7) and (0.60-0.94) respectively. Pb has highest AF (0.09-1.19) in *Corriandrum Sativum. B. campestris* has highest AF (0.27-1.02) for Zn. AF for Mn ranges highest in *T. aestivum.*Accumulation factor is > 1 for all metals except Mn and Cu in most of the tested crops. It showed high accumulation, metals that have high AFmake their way easier to edible parts of food crops than those who have less transfer factor(Khan *et al*., 2013). Hence, these metals accumulate in different food crops in high concentration.

Accumulation factor was observed higher for Pb and Cd and may be taken as one of the possible factors to instigatehuman health risk through consumption of food crops. Metal transfer factor is a key element of heavy metal contact to humans by food chain. For human health risk surveillance calculation of accumulation factor for metals is essential(Rehman *et al*., 2017).

Daily intake of metals (DIM) and human health risk assessment: Findings to evaluate DIM and HRI from metals pollutedtested crops are presented in Tables 3. Daily intake of metals ranges from 0.0003 to 0.002, 0.0002 to 0.0004, 0.004 to 0.005, 0.0004 to 0.007, 0.0002 to 0.0005, 0.005 to 0.02, 0.0001 to 0.32 mg kg^{-1} $person^{-1}$ d^{-1} for Cd,Cr, Ni, Cu,Pb, Zn and Mn respectively. Trend of DIM appeared as: Mn>Zn>Cu>Ni>Cd>Pb>Cr. The HRI values for Cd, Cr, Ni, Cu, Pb, Zn and Mn ranges from 0.56 to 1.96, 0.08 to 0.15, 0.21 to 0.25, 0.01 to 0.2, 0.69 to 1.32, 0.02 to 0.22, 0.07 to 0.23, respectively.

Table 2. Accumulation Factor in food crops around Mehmood Booti dumping site

Plant specie	Statistics	Cd	Cr	Ni	Cu	Pb	Zn	Mn
T. aestivum	**Mean**	0.18	0.6	0.6	0.4	0.2	0.21	0.25
	Min-max	0.1-0.25	0.45-0.72	0.44-0.80	0.34-0.5	0.10-0.30	0.09-0.36	0.24-0.27
A. Sativa	**Mean**	0.20	0.87	0.79	0.25	0.14	0.24	0.14
	Min-max	0.05-0.56	0.65-1.03	0.50-1.03	0.20-0.31	0.04-0.24	0.11-0.41	0.13-0.15
B. campestris	**Mean**	.3000	0.5	0.66	0.24	0.2	0.61	0.16
	Min-max	0.29-0.32	0.25-0.84	0.48-0.86	0.20-0.32	0.07-0.30	0.27-1.02	0.15-0.14
M. Spicata	**Mean**	0.25	0.84	0.63	0.04	0.15	0.55	0.13
	Min-max	0.11-0.67	0.61-1.06	0.46-0.82	0.03-0.05	0.03-0.30	0.24-0.91	0.12-0.13
A. cepa	**Mean**	0.32	0.46	0.67	0.48	0.19	0.66	0.12
	Min-max	0.29-0.36	0.29-0.67	0.48-0.85	0.39-0.61	0.09-0.30	0.30-1.09	0.11-0.13
S. tuberosum	**Mean**	0.37	0.48	0.73	0.03	0.12	0.46	0.11
	Min-max	0.32-0.43	0.11-1.55	0.48-0.86	0.02-0.05	0.02-0.24	0.21-0.77	0.10-0.11
S. oleracea	**Mean**	0.68	0.52	0.77	0.72	0.19	0.09	0.001
	Min-max	0.33-1.71	0.40-0.69	0.54-0.98	0.60-0.94	0.08-0.33	0.04-0.15	0.0008-0.0013
C. sativum	**Mean**	0.26	0.74	0.82	0.94	0.14	0.07	0.08
	Min-max	0.17-0.39	0.37-1.18	0.82-0.82	0.94-0.94	0.09-1.19	0.07-0.07	0.07-0.08

Table 3. Daily intake of metals (DIM) (mg kg^{-1} $person^{-1}$ d^{-1}) and Health risk index (HRI) for individual heavy metals in food crops around Mehmood Booti dumping site.

Plant specie	Index	Cd	Cr	Ni	Cu	Pb	Zn	Mn
T. aestivum	**DIM**	0.002	0.0003	0.004	0.005	0.0005	0.005	0.32
	HRI	0.56	0.1	0.21	0.11	1.32	0.15	0.23
A. Sativa	**DIM**	0.0003	0.0004	0.005	0.003	0.0003	0.007	0.018
	HRI	0.57	0.15	0.23	0.07	0.84	0.02	0.13
B. campestris	**DIM**	0.001	0.0003	0.005	0.0027	0.0004	0.006	0.2
	HRI	0.9	0.09	0.24	0.07	1.27	0.02	0.14
M. spicata	***DIM***	0.001	0.0004	0.004	0.0005	0.0003	0.013	0.016
	HRI	0.74	0.14	0.22	0.01	0.85	0.04	0.11
A.cepa	***DIM***	0.002	0.0002	0.004	0.005	0.0004	0.007	0.015
	HRI	0.97	0.08	0.22	0.13	1.28	0.22	0.11
S. tuberosum	***DIM***	0.002	0.0002	0.005	0.0004	0.0004	0.009	0.013
	HRI	1.1	0.08	0.24	0.01	0.69	0.03	0.09
S. oleracea	***DIM***	0.0003	0.0003	0.005	0.008	0.0004	0.02	0.0001
	HRI	1.96	0.09	0.25	0.2	1.23	0.07	0.001
C. sativum	***DIM***	0.0005	0.0004	0.005	0.007	0.0002	0.005	0.009
	HRI	0.77	0.12	0.21	0.17	1.02	0.02	0.07

The exposure of toxic metals to humans occur through several pathways; inhalation, food ingestion and dermal contact. Human health risk assessment through food chain should be conducted in areas where wastewater irrigation practices are common. Food chain is the key exposure pathway of heavy metals in Human(Rehman *et al.*, 2017).Food crops produced around mehmoodbooti dumping site are taken up by the local population directly or sold to the market. These food crops are taken up daily by local people in their daily meal as salad or in cooked form. *Triticum aestivum* is a cereal crop and used as staple food. Leafy vegetables(*Corriandrum sativum* and *Mentha spicata* etc*)* and *A. cepa* are used as salad almost 1-2 times in their meal daily. Metal contamination of these food crops poses greater health risk. In our study Pb and Cd have HRI >1 which indicate human health risk via food ingestion. Health risk index for Pb and Cd was reported surpassing the allowable limits in cereals and vegetables in previous studies(Khan *et al*.2013;Rehman *et al*. 2017). HRI for Pb is greater than one (>1) in almost all food crops but for Cd it is more than one (>1) only in

Solanum tubersoum and *Spincaia oleracea*. Consumption of these vegetables poses health risk to the local people. So wastewater coming from the dumping site should be treated prior to be used for irrigation.

Conclusion: Plants around the Mehmood Booti dumping site showed high accumulation of metals. People living around the site use these plants as medicines for different ailments and as food. Nine food crops, six wild hurbs and three wild shrubs were studied for metal contents, potential health impacts and safety measures. Prolonged intake of these food crops and wild plants cause chronic accumulation of metals and cause serious impacts on human health. Ni, Cu, Pb and Cd exceeded WHO permissible limits in these plant species. The AF is > 1 for all metals except Mn and Cu in most of the studied crops. The HRI was greater than one for Pb approximately in all food crops. Waste water coming from the dumpsite cause metal pollution in the soil and these metals are then transferred to the plants grown on these soils. So treatment of the wastewater coming from the dumpsite is necessary.

REFERENCES

Aiman, U., Mahmood, A., Waheed, S. & Malik, R.N., 2016. Enrichment, geo-accumulation and risk surveillance of toxic metals for different environmental compartments from Mehmood Booti dumping site, Lahore city, Pakistan. *Chemosphere,* 144**,** 2229-2237.

Ali, Z., Malik, R.N. & Qadir, A., 2013. Heavy metals distribution and risk assessment in soils affected by tannery effluents. *Chemistry and Ecology,* 29**,** 676-692.

Aziz, M.A., Khan, A.H., Adnan, M. & Izatullah, I., 2017. Traditional uses of medicinal plants reported by the indigenous communities and local herbal practitioners of Bajaur Agency, Federally Administrated Tribal Areas, Pakistan. *Journal of Ethnopharmacology,* 198**,** 268-281.

Bora, P.K., Chetry, S., Sharma, D.K. & Saikia, P.M., 2013. Distribution Pattern of Some Heavy Metals in the Soil of Silghat Region of Assam (India), Influenced by Jute Mill Solid Waste. *Journal of Chemistry,* 2013**,** 7.

Boyd, R.S., 2009. High**-** nickel insects and nickel hyperaccumulator plants: A review. *Insect Science,* 16**,** 19-31.

Calo, F.,& Praise, M., 2009. Waste management and problems of groundwater pollution in karst environments in the context of a post-conflict scenario: The case of Mostar (Bosnia Herzegovina). . *Habitat international, ,* 33: **,** 9.

Fatoki, O., 2000. Trace zinc and copper concentrations in roadside vegetation and surface soils: a measurement of local atmospheric pollution in Alice, South Africa. *International Journal of Environmental Studies,* 57**,** 501-513.

Gu, Y.G., Gao, Y.P. & Lin, Q., 2016. Contamination, bioaccessibility and human health risk of heavy metals in exposed-lawn soils from 28 urban parks in southern China's largest city, Guangzhou. *Applied Geochemistry,* 67**,** 52-58.

Han, D., Tong, X., Currell, M.J., Cao, G., Jin, M. & Tong, C., 2014. Evaluation of the impact of an uncontrolled landfill on surrounding groundwater quality, Zhoukou, China. *Journal of Geochemical Exploration,* 136**,** 24-39.

Kanmani, S. & Gandhimathi, R., 2013. Assessment of heavy metal contamination in soil due to leachate migration from an open dumping site. *Applied Water Science,* 3**,** 193-205.

Khan, M. U., R. N. Malik R.N., & Muhammad,S., 2013. Human health risk from Heavy metal via food crops consumption with wastewater irrigation practices in Pakistan. *Chemosphere,* 93, 2230-2238.

Krishna, A.K. & Govil, P.K., 2008. Assessment of heavy metal contamination in soils around Manali industrial area, Chennai, Southern India. *Environmental Geology,* 54**,** 1465-1472.

Mahmood, A., Rashid, S. & Malik, R.N., 2013. Determination of toxic heavy metals in indigenous medicinal plants used in Rawalpindi and Islamabad cities, Pakistan. *Journal of Ethnopharmacology,* 148**,** 158-164.

Mensah, A., 2006. People and their waste in an emergency context: The case of Monrovia, Liberia. *Habitat International,* 30**,** 754-768.

Mubark Ebrahim, A.E., M.A.; Khalid, H.; Noun, Manale; Roumie, M.; Michalke, B., 2014. PIXE as a complement to ICP-OES trace metal analysis in Sudanese medicinal plants. . *Applied Radiation and Isotopes,* 90: **,** 6.

Noli, F. & Tsamos, P., 2016. Concentration of heavy metals and trace elements in soils, waters and vegetables and assessment of health risk in the vicinity of a lignite-fired power plant. *Science of The Total Environment,* 563–564**,** 377-385.

Olowoyo, J.O., Okedeyi, O.O., Mkolo, N.M., Lion, G.N. & Mdakane, S.T.R., 2012. Uptake and translocation of heavy metals by medicinal plants growing around a waste dump site in Pretoria, South Africa. *South African Journal of Botany,* 78**,** 116-121.

Opaluwa O.D., A.M.O., Ogbo L.O., Abiola K.A., Odiba I.E., Abubakar M., Nweze N. , 2012. Heavy metal concentrations in soils, plant leaves and crops grown around dump sites in Lafia Metropolis, Nasarawa State, Nigeria. *Adv. Appl. Sci. Res* 3: **,** 5.

Pastor, J. & Hernández, A.J., 2012. Heavy metals, salts and organic residues in old solid urban waste landfills and surface waters in their discharge areas: Determinants for restoring their impact. *Journal of Environmental Management,* 95, Supplement**,** S42-S49.

Rajan, J.P., Singh, K.B., Kumar, S. & Mishra, R.K., 2014. Trace elements content in the selected medicinal plants traditionally used for curing skin diseases by the natives of Mizoram, India. *Asian Pacific Journal of Tropical Medicine,* 7**,** S410-S414.

Rehman, Z.U., Khan, S., Brusseau, M.L. & Shah, M.T., 2017. Lead and cadmium contamination and exposure risk assessment via consumption of vegetables grown in agricultural soils of five-selected regions of Pakistan. *Chemosphere,* 168**,** 1589-1596.

U.S Environmental Protection Agency. 2007. Protocol 3051A Microwave assisted acid digestion of sediments, sludges, soils, and oils.

U.S Environmental Protection Agency. 2007. Protocol 3052A. Microwave Assisted Acid Digestion of Siliceous and Organically Based Matrices.

Who/Fao, 2007. Joint FAO/WHO Food Standard Programme Codex Alimentarius Commission 13th Session. Report of the Thirty Eight Session of the Codex Committee on Food Hygiene. Houston, United States of America, ALINORM 07/ 30/13.