Appraisal of Heavy Metal Concentrations in Edible Vegetable *Abelmoschus esculentus* (Lady finger) Grown in Soil Irrigated with Domestic Sewage Water in Sargodha, Pakistan

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ABSTRACT

Agricultural use of sewage water usually have a positive effect on the yield of vegetable crops. However, sewage water that contains heavy metals can transfer these elements to soils and plants. An investigation has been carried out to evaluate the contamination levels with metals such as chromium (Cr), manganese (Mn), iron (Fe), molybdenum (Mo), lead (Pb) and cadmium (Cd) in soil, and their subsequent accumulation in *Abelmoschus esculentus* (Lady finger) at two sites in vicinity of District Sargodha, Pakistan. The concentration of heavy metal in the soil at site-I for Cr, Mn, Fe, Mo, Pb and Cd was 0.35, 21.14, 26.63, 10.40, 22.18 and 12.97 mg/kg and at site-II was 0.23, 21.18, 26.40, 10.15, 20.28 and 14.48 mg/kg, respectively. The metal concentration at site-I was higher than site-II except for Cd. The magnitude of contamination in vegetable (*Abelmoschus esculentus*) at the two sites was higher than in the soil. The level of heavy metal (mg/kg dry wt.) in the vegetable at site-I was (in mg/kg) 14.50 for Cr, 54.79 for Mn, 45.24 for Fe, 13.47 for Mo, 1.72 for Pb and 0.24 for Cd and at site-II was 12.26 for Cr, 47.15 for Mn, 49.95 for Fe, 8.92 for Mo, 1.68 for Pb and 0.19 for Cd. Transfer factors in the range of 0.013-52.17mg/kg were obtained, with Cr having the highest transfer factors of 52.17 and 41.42 at site-I and site-II mg/kg, respectively. The pollution load index was 0.04 for Cr, 0.97 for Mn, 0.88 for Fe, 0.43 for Mo, 2.72 for Pb and 1.49 for Cd at site-I and 0.025 for Cr, 0.98 for Mn, 0.87 for Fe, 0.29 for Mo, 2.49 for Pb and 9.72 for Cd at site-II, respectively. Considering the eating habit of inhabitants, the estimated intake rates of heavy metals from consumption of *Abelmoschus esculentus* in mg day^{-1} at site-I was Cr (0.05), Mn (7.68), Fe (0.37), Mo (8.55) , Pb (2.82), Cd (1.36) and at site-II, Cr (0.04), Mn (6.61), Fe (0.41), Mo (5.69) , Pb (2.76), Cd (1.10). The daily ingestion of Mn, Mo, Pb and Cd was beyond the oral reference dose hence, the consumption of *Abelmoschus esculentus* is not considered to be safe for the people living in the sampling area. Thus, although the practice of growing vegetables using wastewater for irrigation is aimed at producing socio-economic benefits, it is not safe and may not be sustainable in the long, as well as in the short termDue to increased consumption of vegetables by urban communities, it is important to treat industrial effluents which are significant sources of heavy metals and phyto-extract excess metals from polluted environments to reduce health risks.

تقدير تركيز العناصر الثقيلة في محصول البامية (*Abelmoschus esculentus* (Lady finger المروية بمياه الصرف الصحي في محافظة سارجودا، باكستان

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المُستلخص

من المعلوم بأن لاستخدام مياه الصرف الصحي في الزراعة انعكاسات ايجابية على إنتاج محاصيل الخضر. إلا أن مياه الصرف الصحي التي تحتوي على العناصر الثقيلة يمكن أن تنقل هذه العناصرإلى التربة ومنها يمكن أن تنتقل إلى النباتات. تم إجراء هذه التجربة في موقعين على محيط محافظة سرغودا في باكستان وذلك لتقييم مستويات التلوث بالمعادن مثل الكروم (Cr)، والمنجنيز (Mn)، والحديد (Fe)، والموليبدنيوم (Mo)، والرصاص (Pb) والكادميوم (Cd) في التربة وتراكمها لاحقا في محصول البامية (*Abelmoschus esculentus* (Lady finger. وكان تركيز العناصرالثقيلة بالموقع الأول بالنسبة للكروم، والمنجنيز، والحديد، والرصاص، والكادميوم هو0.35، 21.14، 26.63، 10.40، 22.18، و12.97ملجم/كجم على التوالي، وفي الموقع الثاني 10.15،26.40،21.18،0.23، 20.28 و14.48ملجم/كجم على التوالي. فيما عدا عنصر الكادميوم. كان تركيز العناصر الثقيلة في الموقع الأول أعلى منه في الموقع الثاني. كما كان حجم التلوث في محصول البامية أعلى من ذلك الذي بالتربة في الموقعين. بلغ مستوى تركيز العناصرالثقيلة (ملجم/ كجم/ مادة جافة) في محصول البامية بالنسبة للكروم 14.5 في الموقع الأول 14.5و 12.26 ملجم/ كجم في الموقع الثاني ، وللمنجنيز 54.79 في الوقع الأول و47.15 ملجم/ كجم في الموقع الثاني ، وللحديد 45.24 في الموقع الأول و49.95 ملجم/ كجم في الموقع الثاني، وللموليبدنيوم 13.47 في الموقع الأول و8.92 ملجم/ كجم في الموقع الثاني ، وللرصاص 1.72 في الموقع الأول 1.72 و1.68 ملجم/ كجم في الموقع الثاني ، وللكادميوم 0.24 في الموقع الأول و1.19 ملجم/ كجم في الموقع الثاني. وجدت معامل الانتقال في حدود 0.13-52.17 مجم/كجم، حيث تصدرها الكروم بمعامل انتقال 52.17 و41.42 مجم/كجم للموقعين الأول والثاني على التوالي. بلغ مؤشر التلوث للكروم 0.04 في الموقع الأول و0.025 في الموقع الثاني، وللمنجنيز0.97 في الموقع الأول و 0.98 في الموقع الثاني، وللحديد 0.88 في الموقع الأول و0.87 في الموقع الثاني، وللموليبدنيوم 0.43 في الموقع الأول و0.29 في الموقع الثاني، وللرصاص2.72 في الموقع الأول و2.49 في الموقع الثاني، وللكادميوم 1.49 في الموقع الأول و9.72 في الموقع الثاني. في إطار أخذ عادات غذاء السكان في الإعتبار يمكن تقديركميات العناصرالثقيلة التي بيننا وكثافتها في محصول البامية محسويه (ملجم/يوم) بمقدار للكروم 0.5 في الموقع الأول 0.5 و 0.4 ملجم/ يوم في الموقع الثاني، وللمنجنيز7.68 في الموقع الأول و6.61 ملجم/ يوم في الموقع الثاني، وللحديد 7.37 في الموقع الأول و45.61 ملجم/ يوم في الموقع الثاني، وللموليبدنيوم 8.55 في الموقع الأول و5.69 ملجم/ يوم في الموقع الثاني، وللرصاص2.82 في الموقع الأول و2.76 ملجم/ يوم في الموقع الثاني، وللكادميوم 1.19 في الموقع الأول و1.10 ملجم/ يوم في الموقع الثاني. وعلى هكذا التقديرات تتعدى كمية التناول اليومي من عناصرالمنجنيز، والموليبدنيوم، والرصاص، والكادميوم النسبة المسموح بها صحياً، مما يعتبر إستهلاك محصول البامية من منطقتي إجراء التجربة بحافظة سرغودا في باكستان غيرأمناً. وعلى هذا وبالرغم من أن ري مزارع الخضروات باستخدام مياه الصرف الصحي يستهدف تحقيق فوائد إقتصادية وإجتماعية مُعتَبَرة ومُقَدَرَة، إلا أنه ليس بأمنٍ، كما وأن مياه الصرف الصحي قد لا يكون مُتَاحاً للإستخدام على المديين الطويل أو حتى الأقصر بسبب إزدياد إستهلاكها نتيجةً لإزدياد زراعة واستهلاك الخضروات في المجتمعات الحَضَرية. وعليه من المهم والضروري مُعَالَجَة مياه الصرف الصحي الصناعي، وإستخلاص العناصرالثقيلة الزائدة في مياه البيئات الملوثة لتقليل المخاطرالصحية الناجمة من إستخدامها في الري.

Introduction

Due to agricultural use of sewage water, the soil is heavily contaminated with metal contents (Mapanda, *et al.,* 2005). When waste products come out of soil, various problems occur in watercourse. If the destruction of plant take place, then heavy metals released back in soil, enrich the soil with pollutants and redistribute in plant tissues. The metal uptake in plant usually occurs via roots or surface of leaves (Sawidis*, et al.,* 2001). Factor on which absorption of heavy metal depends are solubility, different growth stages, soil type, nutrients in the form of fertilizers (Sharma, *et al.,* 2006; Ismail*, et al.,* 2005). Different plants have different abilities to take up these heavy metals and then to remove it and certain evidence shows that most plants have greater capacity to take up these heavy metals, collect in plant body and produce various adverse effects in the consumers (Wenzel and Jackwer, 1999).

Discharge of highly toxic compounds either from industrial sector or from water disposal area is now a great problem. Mostly, this unprocessed water runs into agricultural area where vegetables are grown. In municipal wastewater beside essential nutrients, the concentration of heavy metal is also very high such as Zn, Cd, Pb, Fe, Co, Mn, Ni ...*etc*. (Singh*, et al.,* 2004). Vegetables take up these heavy metals from the soil and the whole food chain is disturbed. One way of the gain of heavy metals is through crops irrigated with raw water. The breakdown of heavy metal in the soil is very difficult so these metals become deposit in the soil. Sign and symptoms in consumer can be slight or can lead to various lethal conditions (Demirezen and Ahmet, 2006). Entrance of metals in body take place either through absorption through skin or by air, food and water. Toxic metals act as competitive agents for various minerals such as Ca and Mg and act as interference in the action of organs in the body. Most important symptoms which appear are pain in stomach and head, diarrhea, metallic taste. In adverse conditions, it may result in loss of conscious and loss of motor reflexes (Nriagu, 1990).

Among the food required for the human body, vegetables are considered as the most important component because they provide calcium, vitamins, iron and proteins, which are very necessary for proper functioning of the body (Arai, 2002). They neutralize the pH of the compounds formed as a result of digestion (Thompson and Kelly, 1990). Okra commonly known as Lady finger *(Abelmoschus esculentus*) belongs to Malvaceae family. It is a herb and grown as sole crop or intercrop with other crops throughout the world in subtropical and tropical regions (Emuh*, et al.,* 2006). The stem of lady finger plant contains fiber, used in paper industry. It contains important nutritional compounds such as minerals, carbohydrates, fats, proteins and vitamins which are deficient in other staple food.

The research was conducted in Sargodha, Pakistan in township areas where vegetables were irrigated with municipal wastewater. The objective of this research is to determine the Cr, Mn, Fe, Mo, Pb, and Cd in soil and vegetable and assess the contamination factor in soil and analyze health risk index due to intake of *Abelmoschus esculentus* in consumers living in sampling area.

Materials and Methods

(1) Samples Collection

(1.1) Sample Collection and Pretreatments

Sargodha city lies in 32°08′00″north latitude and 73°7′00″ east longitude. Vegetables are grown on large scale in this region, to fulfill the demand of the consumers. Lady finger is the most common vegetable at these sites. Two sites were selected for collection of lady finger and soil samples. A total three replicates of vegetable and subsequent soil samples were collected from each site in July and August 2012. Vegetable samples were washed with tap water and with deionized water to remove dust particles. Samples were dried at room temperature and sunlight for two weeks. Then placed into oven at 72 °C for 48 hours. Dried samples were pulverized. Soil samples were taken from each site at 0-20 cm depth from where vegetable samples were taken. Soil samples were air dried at room temperature for two weeks, crushed and pulverized and then oven dried and stored for further analysis.

(1.2) Digestion of Samples

The sample used for digestion was 1 gram. Soil and vegetable samples were digested by H_2O_2 and H_2SO_4 in 2:1. The samples were digested on hot plate and continued until the samples become transparent. Samples were filtered with filter paper and with distilled water, the final volume was maintained up to 50 ml.

(1.3) Detection of Metal Concentrations

Atomic absorption spectrophotometer was used to analyze the metal contents in vegetable and soil (Lindsay and Norvell, 1978). Standard solution of Cr, Mn, Fe, Mo, Pb and Cd were prepared to get the accurate value. From a standard stock solution, a calibration curve was constructed by different metal concentrations.

(1.4) Quality Assurance

To ensure the consistency of results, the quality assurance and safety measures were carried out. To prevent contamination, the samples were handled carefully. During the study, double distilled water was used and glass wares were cleaned carefully. For confirmation of analytical procedures, a study was conceded by homogenizing the analyzed samples with varying quantity of standard solution of metals. The results showed the certified value within ±2%.

(1.5) Statistical Analysis

For statistical analysis, SPSS software version 17 was used. For soil, one way analysis of variance and for vegetable, two way analysis of variance with interaction was used and also find out the correlation between root, edible portion and soil. The significance of means was at 0.001, 0.01 and 0.05 probability level as suggested by (Steel and Torrie, 1980).

(1.6) Transfer Factor for Vegetable/Soil System

To analyze the accumulating capability of metals from soil to vegetable, a quantitative assessment of the correlation between the concentration of metal contents in vegetable and in subsequent soils was done by transfer factor.

$TF = [Metal]_{vegetable} / [Metal]_{soil}$

where: TF stands for transfer factor for vegetable/ soil system;

$[M]_{vegetable}$ is the total metal concentration in the tissue of vegetables, mg kg-^{1}, in dry matter; $[M]_{soil}$ is the total metal concentration in soils where this vegetable is grown, mg kg-^{1}, in dry matter.

(2) Pollution Load Index (PLI)

Pollution load index (PLI), for a particular site, has been evaluated (Liu , *et al.,* 2005).

This parameter is expressed as:

PLI = Metal concentration in investigated soil / Reference value of the metal in soil

(3) Health Risk Index (HRI)

The health risk index was calculated as the ratio of estimated exposure of vegetable sample and oral reference dose (Cui , *et al.,* 2004). Values of R_fD for Cd (0.001 mg kg^{-1} per day), Cr (1.5 mg kg^{-1} per day), Mn (0.041mg/kg), Fe (0.70 mg/kg) and Mo (0.009 mg/kg) were taken from Integrated Risk Information System (USEPA, 2010). The value of R_fD for Pb (0.0035 mg kg^{-1} per day) was taken from World Health Organization, (WHO, 1993). The average daily intake of metals in 0.345 kg of vegetable per day for adult residents was used (Wang , *et al.,* 2005). Daily intake was calculated by the following equation:

Daily intake of metal (DIM) = $C_{metal} \times D_{food\ intake} / B_{average\ weight}$

where C_{metal}, $D_{food\ intake}$ and $B_{average\ weight}$ represent the heavy metal concentrations in vegetable (mgkg^{-1}), daily intake of vegetables (mgkg^{-1} day^{-1}) and average body weight (kg), respectively.

The average daily vegetable intake rate was calculated by conducting a survey where 100 people having average body weight of 60 kg were asked for their daily intake of particular vegetable from the experimental area in each month of sampling (Wang , *et al.,* 2005).

Results

Analysis of variance for data in soil showed significant effect ($P< 0.05$) of sites on Pb and reverse effect ($P>0.05$) was true for Cr, Mn, Fe, Mo and Cd. (table 1).

Table 1: One Way Analysis of Variance of Heavy Metals in Soil at Two Sites

Metals	Cr	Mn	Fe	Mo	Pb	Cd
Sites	0.032^{ns}	0.001^{ns}	1.044^{ns}	0.247^{ns}	9.196^{*}	7.248

(***=significant at 0.01 level/ ns =not significant*)

Analysis of variance with interaction in vegetable showed significant effect of site on all metals while vegetable showed non-significant effect on Cr, Fe and Cd but showed significant effect on Mn, Mo and Pb concentration (table 2).

Table 2: Analysis of Variance with Interaction of Heavy Metals in *Abelmoschus Esculentus* at Two Sites.

Heavy Metals	Site	Vegetable	Site×Vegetable
Cr	12.485^{ns}	6.092^{ns}	3.837^{ns}
Mn	92.089^{ns}	283.97^{*}	83.060^{ns}
Fe	15.129^{ns}	121.52^{ns}	58.516^{ns}
Mo	6.016^{ns}	45.578^{**}	75.877^{**}
Pb	0.008^{ns}	13.210^{***}	$7.994E\text{-}5^{ns}$
Cd	0.011^{ns}	0.000^{ns}	$5.521E\text{-}5^{ns}$

(*=significant at 0.05 level / **=significant at 0.01 level/ ***= significant at 0.001level/ ns =not significant)

(1) Heavy Metals in Soil

At both sites, the level of heavy metals in raw water irrigated soil from where the vegetable Lady finger (*Abelmoschus esculentus*) samples were taken, was found below the maximum permissible limit except Pb (USEPA, 1997). The concentration of all heavy metals investigated were lower at site-II than that at site-I of sampling area except Cd (table 3). At site-I the concentration of Cr (0.35), Mn (21.14), Fe (26.63), Mo (10.40), Cd (12.97), Pb (22.18) and at site-II the Cr (0.23), Mn (21.18), Fe (26.40), Mo (10.15), Cd (14.48), Pb (20.28) mg/kg, respectively.

Table 3: Concentration in mg/kg of some Heavy Metal Pollutants in Soil Samples Obtain from two Different Sites of District Sargodha, Pakistan

Heavy metals	Sampling sites		Permissible maximum limit
	Site I (means±SE)	Site II (means±SE)	
Cr	0.35±0.002	0.234±0.010	400
Mn	21.14±0.143	21.18±0.262	80
Fe	26.63±0.146	26.40±0.302	21000
Mo	10.40±0.345	10.15±0.027	40
Pb	22.18±0.318	20.28±0.143	300
Cd	12.97±0.29	14.48±0.145	3

(2) Heavy Metals in Edible Parts of Vegetables

The total concentration of heavy metals in vegetable Lady finger (*Abelmoschus esculentus*) collected from two sites in sub-urban area of Sargodha city are present in table 4.

Table 4: Concentration in mg/kg of some Heavy Metal Pollutants in Lady finger (*Abelmoschus esculentus)* Obtain from Two Different Sites of District Sargodha, Pakistan

Heavy metals	Sampling sites		Permissible maximum limit
	Site I (means±SE)	Site II (means±SE)	
Cr	14.50±0.269	12.26±0.289	50
Mn	54.79±0.143	47.15±0.131	30
Fe	45.24±0.259	49.95±0.093	1000
Mo	13.47±0.187	8.92±0.129	5
Pb	1.72±0.272	1.68±0.129	10
Cd	0.237±0.025	0.192±0.023	0.5

(2.1) Concentration of Cr in the vegetable tissue (dry wt.) average 14.50 mg/kg at site-I and 12.26 mg/kg at site-II, respectively. While, in all samples, Cr level was lower than permissible limit of 50 mg/kg dry wt. (WHO standards), (WHO 1996). The vegetable Cr concentration was however higher at site-II than at site-I statistically and also below the tolerable limits of 23 mg/kg (Weigtre, 1991).

(2.2) Mn concentration in the vegetable parts average 47.15 mg/kg at site-II and 54.79 mg/kg at site-I, respectively. Higher concentration was observed at site-II than site-I. The concentration of Mn in vegetable tissue exceeded the permissible limit of 30 mg/kg (WHO standards), (WHO 1996).

(2.3) Fe concentration in the vegetable tissue average 45.24 mg/kg at site-II and 49.95 mg/kg at site-I respectively. Fe concentration at both sites in the vegetable did not exceed the permissible limit of 1000 mg/kg (WHO standards), (WHO 1996).

(2.4) Mo concentration in vegetable Lady finger (*Abelmoschus esculentus*) average 13.47 mg/kg at site-I and 8.92 mg/kg at site-II, respectively and were significantly higher at site-I than site-II. Mo concentration in the vegetable tissues at both sites of sampling was above permissible limit

(2.5) Cd level in edible parts of Lady finger (*Abelmoschus esculentus*) average 0.23 mg/kg at site-I and 0.19 mg/kg at site-II of sampling. The level of Cd in vegetable tissue did not exceed the permissible limit of 0.5-2 mg/kg (Codex and Alimentarius, 2001).

(2.6) Pb concentration in tissues of the vegetable average 1.72 mg/kg at site-I and 1.68 mg/kg at site-II, respectively and with considerably higher level at site-I than at site–II found in this investigation. The Pb concentration at both sites of sampling area of vegetable did not exceed the permissible limit of 3-10 mg/kg (Codex and Alimentarius, 2001).

The average transfer factor of the selected heavy metal at site- I and at site-II calculated as the concentration of metals in tissues of vegetable related to concentration in soil range from 0.013-52.17 mg/kg depending upon the metal concentration (table 5).

Table 5: Transfer Factor of Each Metal in Lady finger (*Abelmoschus esculentus*) from soil to Vegetable

Sampling area	Heavy metals					
	Cr	Mn	Fe	Mo	Pb	Cd
Site I	41.42	2.59	1.698	1.295	0.077	0.018
Site II	52.17	2.225	1.891	0.878	0.083	0.013

Transfer factor was in order TF Cr (41.42)>TF Mn (2.59)>TF Fe (1.69) >TF Mo (1.29) >Pb (0.07)>TF>Cd (0.018) at site-I and at site-II, TF Cr (52.17)>TF Mn (2.22)>TF Fe (1.89) >TF Mo (0.87)>Pb (0.08) >TF>Cd (0.013), respectively. Cr (r=-0.42), Fe (r=-0.55), Pb (r=-0.38) and Cd (r=-0.49) showed negative and non-significant correlation between soil-vegetable while Mn (r=-0.77) showed significant correlation. Mo (r=0.13) showed positive and non-significant correlation between soil and vegetable (table 6).

Table 6: Heavy Metal Correlation Between Soil and vegetable

Heavy metals	Cr	Mn	Fe	Mo	Pb	Cd
Soil-vegetable	-0.422	-0.771**	-0.552	-0.136	-0.388	-0.498

(* *Correlation is significant at the 0.01 level & at the 0.05 level (2-tailed)*).

Pollution severity and its variation along the sites were determined with the use of pollution load index. The contamination factor at site-I was greater as compared to site-II except Cd (table 7).

Table 7: Pollution load index (Contamination factor) for heavy metals (mg/kg) in soil

Sampling area	Pollution load index					
	Cr	Mn	Fe	Mo	Pb	Cd
Site I	0.04	0.979	0.882	0.431	2.721	8.704
Site II	0.025	0.980	0.874	0.292	2.488	9.718

The reference value of Cd, Pb, and Cr in soil was 1.49, 8.15 and 9.07µg/g (Singh , et al., 2010a). Mo was lower at site-I and site-II as compared to reference value which was 3.0mg/kg dry matter (Dutch standards, 2000). The reference value of Mn was 46.75mg/kg which was higher than present value (Singh , *et al.,* 2010b). The concentration of Cr and Fe at both sites was also lower than the reference value of Cr and Fe which was 9.07 (Singh*, et al.,* 2010a) and 56.90mg/kg (Dosumu*, et al.,* 2005). The pollution load index at site-I was in sequence: Cd(8.70)>Pb(2.72)>Mn(0.97)>Fe(0.88))>Cr(0.04), and at site-II was Cd (9.71)>Pb(2.49)> Mn(0.98)>Fe(0.87)>Mo(0.29)>Cr(0.02).

The health risk due to intake of heavy metals via Lady finger (*Abelmoschus esculentus*) ranges from 0.04-36.44. The risk index at site-I was in the order: Mo(8.55)>Mn(7.68)>Pb(2.82)Cd (1.36)> Fe(0.37)>Cr(0.05)>Co(0.08) and at site-II was in the order: Mn(6.61)>Mo(5.68)>Pb(2.76) Cd(1.104)>Fe (0.41))>Cr(0.04). Highest risk index was observed for Mo at site-I and at site-II was due to Mn and lowest health risk was due to Co at both sites (table 8).

Table 8: Health Risk Intake (HRI) of Heavy Metal via Intake of
Lady finger (*Abelmoschus esculentus*) from Waste Water Irrigated Sites

Sampling area	Health risk intake (mg day^{-1})					
	Cr	Mn	Fe	Mo	Pb	Cd
Site I	0.05	7.68	0.37	8.55	2.82	1.36
Site II	0.04	6.61	0.41	5.68	2.76	1.10

Discussion

The heavy metals in the waste water sites were lower than the permissible limit (see, table 3). The lower concentration of heavy metals in the site irrigated with waste water was due to the continuous removal of heavy metals by the vegetables and cereals grown the area and also due to leaching of heavy metals into the deeper layer of the soil (Singh, *et al.,* 2010a). The mean concentration of Cd in Lady finger (*Abelmoschus esculentus*) harvested from soil exposed to wastewater was found to be above the WHO maximum permissible limits (see, table 4). On the other hand, Cr, Mn, Fe, and Pb were lower than the acceptable limit. Mn concentration was higher (54.79 mg/kg) in lady's finger at site I and while, Fe concentration was higher (49.95 mg/kg) at site-II. The observed value of Pb during the present study was higher than the value 8.15 mg/kg recorded by (Singh, *et al.* 2010a) in wastewater irrigated soil from the agricultural field of the dry tropical areas of India.

The transfer factor between soil and vegetable for metal was in the order: Cr>Mn>Fe>Mo>Pb>Cd (see, table 5). At site I and II, the transfer factor of Cr was higher (41.42 and 52.17 mg/kg) and due to Cd was lower (0.018 and 0.013 mg/kg). Higher values of transfer factor suggests poor retention of metals in soil and/or more translocation in plants. (Singh, *et al.,* 2010a) recorded that the transfer of Cr from wastewater site to lady finger was 14.35µg/g which was lower than present study.

In this study, Mo showed positive and non-significant correlation between soil and vegetable, which indicates strong relationship between them while reverse was true for Mn. Cr, Fe, Pb and Cd showed negative and non-significant correlation between soil and vegetable (see, table 6). Pb correlation(r=0.95) was positive and significant while Cr correlation (r=-0.41) was negative and non-significant in lady finger, collected from dry tropical areas of India (Singh , *et al.,* 2010a). (Sinha, *et al.,* 2006) have also found positive and negative correlations between heavy metal concentrations of plants and soil, which may be due to multiple interactions among heavy metals for uptake in the plants (An , *et al.,* 2004).

The accurate and reliable method for monitoring of metal pollution in waste water site is metal pollution index (Usero*, et al.,* 1997). The pollution load index was in sequence Cd>Pb>Mn>Fe>Mo>Cr at both sites. The PLI observed for Cd and Pb was greater than 1, due to large number of distinct sources like anthropogenic outputs, agricultural runoff and industrial activities. The contamination factor for Cr, Mn, Fe and Mo was less than 1 (see, table7). However, relatively higher PLI values at sewage might be due to increased human activity since these are township areas having higher population and establishments. Pollution severity and its variation along the sites were determined with the use of pollution load index. Higher metal pollution index in lady finger has been recorded by (Singh, *et al.,* 2010a), which suggests that this vegetable may cause more human health risk due to higher accumulation of heavy metals in the edible portion. These confirmed that studied area is facing probable environmental pollution especially with dangerous metal contents which result from increased rate of non-treatment industrial waste which are discharged to irrigated water.

If the index greater than or equal to 1 then, it would not considered to be safe and is a great risk to human (USEPA, 2002). In the current study, the risk index due to metal was in such sequence: Mo>Mn>Pb>Cd>Fe>Cr at site-I and at site-II was Mn>Mo>Pb>Cd>Fe>Cr, respectively. The risk index was greater than 1 for Mn, Mo, Pb and Cd while the risk index for Cr and Fe was less than 1 (see, table 8). According to (Singh, *et al.,* 2010a) the health risk due to Cd was 5.08 mg per day due to intake of lady finger in tropical areas of India, which was higher than the present study. The results of current study indicates that the inhabitants around waste processing sites are possibly exposed to health risks due to Mo, Mn, Pb and Cd by consuming vegetables grown in nearby areas.

Conclusion

Wastewater irrigation led to the accumulation of heavy metals in soil and consequently into the vegetable. Heavy metal concentrations varied in the tested vegetable, which reflect the differences in the uptake capabilities and further translocation to edible portion of the Lady finger. The long term use of wastewater in irrigation resulted in increased heavy metal concentrations namely Cr, Mo, Mn, Pb, Cd and Fe in soil. These metals are then transferred to plants before being transferred to the human body. This is a potential health risk to the urban farmers who make use of many vacant lands which have been exposed to wastewater for growing vegetables. There is therefore need for satisfactory soil quality monitoring procedures so as to prevent potential health hazards of wastewater application on agricultural land. Even though a number of methods dealing with heavy metal removal have been investigated such as those involving addition of substances that bind metals to form sparingly soluble compounds which are not leached by rain, future studies in Pakistan should consider biological removal of heavy metals by intercropping vegetables with local agro forestry tree/shrub species in soils irrigated with wastewater.

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