Research Paper

Human health risk assessment through the comparative analysis of diverse irrigation regimes for Luffa (Luffa cylindrica (L.) Roem.)

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ABSTRACT

In the present study, the effects of untreated wastewater and associated health risks were assessed in an abundantly consumed vegetable, Luffa cylindrica. In this direction, trace metal accumulations in L. cylindrica samples irrigated with three different water regimes (municipal wastewater, groundwater, and canal water) were determined. The metal levels were defined by atomic absorption spectrophotometer equipped with a graphite furnace and D2 corrector. Trace metal concentrations in L. cylindrica samples were in the range of 7.91–9.01, 3.78–4.22, 0.54–0.63, 39.18–43.27, 15.76–20.82, 29.04–42.49, 6.96–8.24, 5.85–7.72, 4.06–4.39 and 0.18–0.42 mg/kg for Mo, As, Se, Fe, Cu, Zn, Ni, Pb, Cd and Co, respectively. The health risk index values of As, Cd, Pb, Mo, Ni, Se and Co; and pollution load index values of As, Mo, Ni, Cu, Cd and Pb were high, indicating possible phytotoxicity. As had the highest value for the pollution load index suggesting high-risk levels. High levels of some metals could be an alarm call for consumers as the vegetable is irrigated with untreated wastewater.

Key words | health risk, Luffa cylindrica, municipal wastewater, trace metals

INTRODUCTION

The prolonged use of wastewater for agricultural purposes results in increased concentration of trace metals in soil and vegetable tissues exceeding the acceptable ranges (Khan et al. 2020). Such accumulation of metallic elements in cultivation fields severely impacts food quality and crop yield (Unver et al. 2015; Khan et al. 2018a). Even canal water used for irrigation becomes contaminated due to the mixing of industrial discharge and domestic waste. The metals from these sources further contaminate the soils and vegetables, ultimately entering human bodies and affecting health (Dogan et al. 2014a, 2014b; Sahin et al. 2016; Ugulu et al. 2019a, 2019b). Water shortage is a major problem in Pakistan and the province of Punjab is no major exception despite its extensive canal system (Khan et al. 2018b, 2018c). Population growth has put a burden on existing resources (Yorek et al. 2016; Ugulu 2020). Bhakkar, a district in Punjab, is topographically a desert and few canals supply agricultural water. However, a few areas in the periphery of the city are deprived of canal water and farmers mainly use tube wells to pump out water for cultivation. In the absence of enough groundwater, the focus is shifted onto municipal wastewater being drained in sewage pipes (Nadeem et al. 2019). Agricultural communities use wastewater for vegetable cultivation.
whereas groundwater is used for the production of cereal crops (Khan et al. 2019a, 2019b). The high amount of nutrients, such as P, K, Cu, Co, Zn, Mo, Fe, Pb, etc., in wastewater resulted in its use for cultivation. Despite having high nutritious components, some toxic metals such as Hg, Ni, As, Pb etc. can potentially accumulate in vegetables up to dangerous levels after prolonged and continuous use of wastewater (Ugulu et al. 2016; Ahmad et al. 2019).

Within the framework of the wastewater irrigation and multiplicity of trace metals in vegetables and effects on food quality, the present study was performed on Luffa cylindrica to ascertain metal levels and impacts on physical attributes of the plant. The bioconcentration factor and correlation highlighting the movement of metals from soil and water from plant tissues were also estimated. Finally, potential health risks were calculated through a
pollution load index and enrichment coefficient in
*L. cylindrica*.

**Economical and ethnobotanical importance of the *Luffa cylindrica***

The current research was undertaken to estimate the extent of contamination in locally and widely consumed luffa vegetable, *Luffa cylindrica* (L.) Roem. (Cucurbitaceae) (Ugulu 2012). Its common name is ‘tori’ and local Asian communities have a special fondness for this vegetable. It is an herbaceous annual climber. The species spreads in Africa as wild but it is distributed in the tropics and subtropics widely, as a cultivated and naturalized plant. Young fruits of the plant are consumed fresh or cooked as a vegetable (Ugulu et al. 2009). In addition to the fruit, leaves are also used as a vegetable (Dogan et al. 2013). Seeds are edible after roasting and edible oil is produced from the seeds of the plant (Ugulu & Baslar 2010; PROTA 2017).

**MATERIALS AND METHODS**

**Study area**

The selected study site was located in the district of Bhakkar, Punjab, Pakistan with the geographical location of 31° 10’ and 32° 22’ N. and 70° 47’ and 72° E. Bhakkar spans an area of 8,120 km². The maximum summer temperature often exceeds 49°C in May and June and the minimum winter temperature is 5°C. Mean annual rainfall is quite low, i.e. 180–200 mm. These climatic conditions are favourable for cereal crop cultivation and vegetables.

**Sample collection**

The fruits of *Luffa cylindrica* (L.) Roem., Cucurbitaceae, were sampled along with corresponding soils and waters in three replicates of each from three different sites. Site CWI (canal water irrigation) was irrigated with canal water, Site GWI (groundwater irrigation) was irrigated with groundwater and Site MWI (municipal water irrigation) was irrigated with municipal wastewater. The soil was removed from the fruits of luffa plants by washing the vegetable with fresh water. The soil and vegetable samples were dried for 48 hours at 105°C.

**Sample preparation**

Collected water, soil and plant samples were digested in accordance with the wet digestion procedure (Ahmad et al. 2018). Acid digestion of samples was performed by placing a 1 g sample in a flask and adding 4 mL of H2SO4 and 8 mL of H2O2 and then placing the mixture in the digestion chamber for about 30 min. When fumes stopped to evaporate, the sample from the digestion chamber was removed and 2 mL of H2O2 were added and heated again in the digestion chamber. The repetition of the process rendered the samples colourless. The volumes of the digested samples were then brought to 50 mL by adding distilled water. The samples were stored in labelled plastic bottles for later use.

**Trace metal analysis**

Trace metals analysed in this study were molybdenum (Mo), arsenic (As), selenium (Se), iron (Fe), copper (Cu), zinc (Zn), nickel (Ni), lead (Pb), cadmium (Cd), and cobalt (Co). The trace metal levels in the soil, water and plant samples were determined by atomic absorption spectrophotometer equipped with a graphite furnace and D2 corrector (Perkin–Elmer Model 503). However, Se and As concentrations in the soil and plant samples were determined by fluorometric method and flow injection hydride generation AAS (Perkin Elmer Aanalyst 400) using arsenate as a standard. Quality control procedures were strictly followed for the entire sample to ensure the quality of results. Analytical grade calibration standards were used for instrument calibration, purchased from Merck (Germany). Precision and accuracy of analyses were ensured through repeated samples against the National Institute of Standard Technology, Standard Reference Material (SRM 1570) for all trace metals. The operating conditions for the respective trace metals are given in Table 1.

**Statistical analysis**

Using SPSS 21, mean levels of trace metals were calculated in samples. All the results were subjected to one-way
ANOVA (Ugulu 2015c). The Pearson correlation coefficient was employed to establish a correlation between soil and vegetable metals.

Bioconcentration factor (BCF)

Bioconcentration factor refers to metal accumulation in the plant as a result of the heavy metal transition from soil to plant. It was used to evaluate the uptake of trace metals from soil and their bioaccumulation in vegetable using the following formula:

$$\text{BCF} = \frac{\text{level of metal in vegetable}}{\text{level of metal in soil}}$$

Pollution load index (PLI)

Based on the concentration factor of each metal in the soil, PLI gave us an estimation to the metal contamination status and the necessary action that should be taken. PLI was estimated as given by Liu et al. (2005). The following equation was used to calculate the PLI values for each treatment:

$$\text{PLI} = \frac{\text{metal in examine soil}}{\text{standard amount of metal in soil}}$$

Health risk index (HRI)

HRI was measured to determine the overall risks of exposure to all trace metals via ingestion of food crops. This shows the risk to people who consume contaminated foodstuffs. It is defined as a ratio of daily intake of metals in food crops to the oral reference dose (USEPA 2002). HRI was calculated as per the following equation:

$$\text{HRI} = \frac{\text{estimated daily intake of metals}}{\text{oral reference dose}}$$

Enrichment coefficient (EC)

EC for the vegetable/soil system was also calculated to assess the accumulating capability of trace metals from soils to vegetable. The EC was calculated as per the following equation:

$$\text{EC} = \frac{\text{metal vegetable/metal soil (sample)}}{\text{metal vegetable/metal soil (control)}}$$

RESULTS AND DISCUSSION

Trace metals in irrigation waters

Trace metals concentrations in the irrigation water samples were in the range of 0.518–0.936 for Mo, 0.410–0.779 for As, 0.229–0.613 for Se, 48.398–58.703 for Fe, 0.355–0.831 for Cu, 0.378–0.560 for Zn, 4.551–5.752 for Ni, 3.544–5.499 for Pb, 0.026–0.070 for Cd and 2.367–4.376 for Co mg/L (Table 2). For all trace metals, while the highest trace metal concentrations were observed at the MWI site, except for Cd, the lowest trace metal concentrations were observed at the CWI site, except for Mo. According to the statistical analysis, the treatments have a non-significant effect ($p > 0.05$) on concentrations of metals in water samples collected from three sites for all metals (Table 3).
The maximum permissible limits of Mo, As, Se, Fe, Cu, Zn, Ni, Pb, Cd and Co in water were reported by USEPA (2002) and WHO, FAO and the Standard Guidelines in Europe (Chiroma et al. 2014) as 0.01, 0.1, 0.02, 5, 0.2, 2, 0.2, 0.1, 0.01 and 0.05 mg/L, respectively. In this study, trace metal values were higher than those in water samples except for Zn. Due to these higher values, it can be said that the water sources used for irrigation are contaminated in terms of heavy metal accumulation. Singh et al. (2010) determined the lower ranges of Cu, Pb, Ni and Zn levels as 0.00–0.203, 0.012–0.088, 0.01–0.22 and 0.023–0.18 mg/L, respectively, in the treated and untreated sewage water.
samples for irrigating the agricultural fields of Dinapur area of Varanasi, Pakistan. Khan et al. (2018d) reported the trace metal values in groundwater, canal water and industrial water samples collected from Khushab, another district in Pakistan, as 1.69, 1.76 and 1.88 mg/L for Cd, 0.54, 0.57 and 0.65 mg/L for Cr, 0.01, 0.02 and 0.03 mg/L for Cu, 0.64, 0.72 and 0.83 mg/L for Fe, 0.08, 0.10 and 0.14 mg/L for Ni, 0.57, 0.61 and 0.66 mg/L for Zn and 0.07, 0.08 and 0.12 mg/L for Mn, respectively. They also stated that concentrations of these metals in water samples were higher than the prescribed maximum permissible limits by the WWF (2007). High trace metal levels observed in this and the present study may be caused by different factors such as urban wastes, aerosols and soil erosion (Khan et al. 2019c, 2019d; Ugulu 2019). However, there were no significant differences in mean metal concentrations between groundwater, canal water and municipal water samples.

### Trace metals in soil samples

The presence of high concentrations of trace metals in soil and vegetable samples is a global issue. In the present study, trace metal accumulations in soil samples collected from CWI, GWI and SWI sites from Bhakkar District are as follows: The contents of Mo, As, Se, Fe, Cu, Zn, Ni, Pb, Cd and Co were in the range of 5.587–46.852, 2.652–26.98, 5.842–6.652, 3.708–3.755, 2.677–3.490, 43.078–46.852, 27.375–27.898, 3.223–3.338, and 8.632–9.148 mg/kg, respectively (Table 2). According to the statistical analysis, the treatments have a significant effect ($p < 0.05$) on concentrations of metals in *L. cylindrica* samples collected from three sites for Pb, Zn and Co values (Table 3).

The maximum permissible limits of Mo, As, Se, Fe, Cu, Zn, Ni, Pb, Cd and Co in soil were reported by USEPA (2002) as 40, 40, 3, 21,000, 50, 200, 50, 300, 3 and 65 mg/kg, respectively. The concentrations of metals studied were below these limits in all treatment conditions except Mo, As and Cd (Table 2). Manzoor et al. (2004) investigated the accumulation of Cr, Fe, Cd, Ni and Zn in the soil in the area irrigated with the wastewater of Hattar Industrial Zone. As a result of the study, they found an average concentration of 0.370, 1.082, 0.017, 0.180 and 0.055 mg/kg higher than these study findings. Continuous uptake of trace metals with plants and penetration into deeper soil layers can be a possible reason for the relatively low levels of these metals in soils, even in areas irrigated with wastewater (Singh et al. 2018; Ugulu et al. 2019c), as the geological composition of soils affects the concentrations of trace metals in agricultural lands. Also, more fertilizer use and atmospheric accumulation may be the cause of higher Cd levels. On the other hand, the various metal profiles in the soil samples were possibly due to different cultivation methods and environmental conditions between the sites. Because of relatively high Cd, Mo and As levels in the soil samples irrigated with canal water and wastewater, it can be said that these waterways have higher levels of effluent matter, probably originating from industrial sources (Khan et al. 2018). According to the results of the present study, there was a remarkable difference in the metal profile of the soil from the three areas. Differences in metal levels in soils of the three sites may be reflective of edaphic factors and diversity of agricultural practices.

Comparing the present findings with other studies performed in Punjab Province, Ahmad et al. (2016a) determined trace metal values between 42.24–47.17, 1.70–2.76, 8.65–20.30, 34.09–42.05, 4.33–6.40, 3.31–3.69 and 13.4–19.7 mg/kg for As, Se, Cd, Fe, Zn, Cu and Co, respectively in Khushab District. Ahmad et al. (2016b) determined the

### Table 3 | Analysis of heavy metals in water, soil and *L. cylindrica*

| Source of variation | Mo     | As     | Se     | Fe     | Cu     | Zn     | Ni     | Pb     | Cd     | Co     |
|---------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Water               | 0.144**| 0.121**| 0.113**| 104.6**| 0.217**| 0.027**| 0.292**| 2.89** | 0.001**| 3.128**|
| Soil                | 0.753**| 69.48**| 0.002**| 0.596**| 0.002**| 0.499**| 13.546**| 0.229**| 0.012**| 0.254**|
| Vegetable           | 0.901**| 0.197**| 0.006**| 12.695**| 19.386**| 144.000**| 1.439**| 2.793**| 0.084**| 0.042**|

*Significant at 0.05 and 0.01; ns: non-significant.
However, the soils in all sites had higher pH levels, whereas property values differed between the soils of different sites; for example, the soil treated with sewage water had higher general property values. These diverse findings may be due to differences in trace metal resources and soil composition of the research area.

**Physicochemical characteristics of soil**

Soil samples were analysed for basic physicochemical parameters such as pH, electrical conductivity, and organic content (Table 4). Organic content remained the highest at MWI (0.93%). CWI soil had the highest phosphorus (8.4 ppm) and nitrogen content (0.043%) whereas the highest potassium level was recorded for MWI soil (189 ppm). The pH level varied between 8.5 (CWI) and 8.8 (MWI). Electrical conductivity levels were similar for soil at CWI and GWI, i.e. 1.3 dS/m.

The levels of pH and electrical conductivity varied between the soils of different sites; for example, the soil treated with sewage water had higher general property values. However, the soils in all sites had higher pH levels, whereas they had lower electrical conductivity than those proposed by Murtaza et al. (2003).

**Trace metal accumulation in vegetables**

Trace metal concentrations in *L. cylindrica* samples were in the range of 7.91–9.01, 3.78–4.22, 0.54–0.63, 39.18–43.27, 15.76–20.82, 29.04–42.49, 6.96–8.24, 5.85–7.72, 4.06–4.39 and 0.18–0.42 mg/kg for Mo, As, Se, Fe, Cu, Zn, Ni, Pb, Cd and Co, respectively. In treatment-I (CWI), the mean metal concentrations in *L. cylindrica* samples were in the order: Fe > Zn > Cu > Mo > Ni > Pb > Cd > As > Se > Co. In treatment-II (GWI) and treatment-III (MWI), the mean concentrations were in the order Fe > Zn > Cu > Ni > Mo > Pb > Cd > As > Se > Co and Zn > Fe > Cu > Mo > Ni > Pb > Cd > As > Se > Co, respectively. Among the three treatments, the mean Fe and Zn concentrations were higher in all treatments and the mean Se and Co concentrations were lesser in all treatments. According to the statistical analysis, the treatments have a significant effect (p > 0.05) on concentrations of metals in *L. cylindrica* samples collected from three sites for Pb, Zn and Co values (Table 3).

The maximum permissible limits of Mo, As, Se, Fe, Cu, Zn, Ni, Pb, Cd and Co in plants were reported by the Standard Guidelines in Europe (Chiroma et al. 2014), FAO/WHO (2001) and WHO (1996) as 5, 7, 425, 20, 100, 67, 10, 2 and 50 mg/kg, respectively. The range values of trace metal accumulation in *L. cylindrica* samples in the present study were lower than these permissible maximum limits in plant samples except for Mo and Cd. Also, the Cd concentration was considerably higher than the values (0.002–0.08 mg/kg) reported by Dogheim et al. (2004) in Egypt. However, the present Cd values were lesser than the vegetables studied by Gupta et al. (2013) in India (10.37–17.79 mg/kg) and within the range (0.03–0.73 mg/kg) noted by Liu et al. (2005) in China. Demirezen & Aksoy (2006) examined various vegetables and determined that Zn contents were in the range of 3.56–4.59 mg/kg which was higher than the present study. The Cr, Ni and Cd values in the present study were lesser than the values reported by Parveen et al. (2012) at 0.8, 0.4 and 0.4 mg/kg, respectively. The range values of different trace metals in vegetables determined by Arora et al. (2008) were

| Table 4 | Physical properties of corresponding soil of *L. cylindrica* |
|---------|-----------------------------------------------------|
| **Property** | **Value** |
| **CWI** | **GWII** | **MWII** |
| Class of texture | Loam | Sandy loam | Loam |
| Saturation | 40 | 32 | 44 |
| pH | 8.5 | 8.2 | 8.8 |
| EC (dSm⁻¹) | 1.3 | 1.3 | 1.4 |
| Organic matter % | 0.93 | 0.77 | 0.88 |
| Total N% | 0.043 | 0.038 | 0.042 |
| Total P (ppm) | 8.4 | 7.8 | 8.0 |
| Total K (ppm) | 176 | 170 | 189 |
116–378, 12–69, 5.2–16.8 and 22–46 mg/kg for Fe, Mn, Cu and Zn, respectively. These results may be because their vegetables were cultivated in sewage water.

Khan et al. (2016, 2018d) used Abelmoschus esculentus samples as the study material in the Jhang and Bhakkar districts of Punjab, Pakistan respectively. These researchers determined the trace metal values were in the range of 9.15–11.20, 0.54–0.55, 0.27–0.48, 39.39–42.94, 55.71–60.27, 20.55–23.51 and 0.48–0.49 mg/kg As, Se, Cd, Fe, Zn, Cu and Co, respectively in Jhang and metal values of 7.003–9.291, 2.800–3.585, 0.378–0.485, 39.718–44.048, 11.791–19.840, 28.203–37.051, 6.085–9.350, 4.885–7.061, 3.375–4.198, and 0.128–0.328 mg/kg for Mo, As, Se, Fe, Cu, Zn, Ni, Pb, Cd and Co, respectively in Bhakkar. Studied metal concentrations in vegetable samples by these researchers were higher than the recorded values in the present study. The differences in the findings between these researches may depend on the different study sites and the accumulation characteristics of the plants utilized in the researches (Ugulu 2015a, 2015b).

**Correlation coefficient of trace metals**

The Pearson correlation coefficient was used to establish a correlation between the metal values of the soil and vegetable samples. Comparative results were obtained for different metals. Positive but non-significant correlation was obtained for As (0.414), Se (0.038), Zn (0.524), Ni (0.576), Pb (0.051) and Cd (0.515) while non-significant but negative correlation was found for Mo (−0.408), Fe (−0.267), Cu (−0.072) and Co (−0.019) (Table 5). Metal accessibility determines the correlation between metal contents in soil and plants. A balanced flow of metals from soil to plants was suggested by a higher value of correlation. Positive and negative results between metal concentrations of vegetables and soil were also recorded by Singh et al. (2010). These different results may result from the various mechanisms of vegetables to take different metals and metalloids. The positive relationship indicates the coexistence and progression of trace metals in soil metals, whereas the negative correlation shows the competition of inclusion of the same destinations in the soil cross-section.

**Table 5** | Correlation between soil and edible part of *L. cylindrica* for different heavy metals

| Metal | Correlation |
|-------|-------------|
| Mo    | −0.408**ns**|
| As    | 0.414**ns** |
| Se    | 0.038**ns** |
| Fe    | −0.267**ns**|
| Cu    | −0.072**ns**|
| Zn    | 0.524**ns** |
| Ni    | 0.576**ns** |
| Pb    | 0.031**ns** |
| Cd    | 0.515**ns** |
| Co    | −0.019**ns**|

*ns* – non-significant.

**Bioconcentration factor of trace metals**

Metal translocation from soil to plants was studied under the bioconcentration factor. Translocation of metals to the edible part of *L. cylindrica* via soil irrigated with wastewater resulted due to bioaccumulation and hence bioavailability of metals. According to the analysis of studied metals, Zn showed the maximum and Co showed the minimum value in three irrigations. The orders of the BCF values for canal water irrigation, groundwater irrigation and municipal water irrigation were: Zn > Fe > Cu > Mo > Cd > Se > Pb > Ni > As > Co, Zn > Fe > Cu > Cd > Mo > Pb > Se > Ni > As > Co and Zn > Fe > Cu > Mo > Cd > Se > Pb > Ni > As > Co, respectively (Table 6).

The bioconcentration factor is one of the best ways to determine the availability of important metals transferred from soil to grow vegetable. Values of Zn, Fe, Cu, Cd and Mo were higher than 1, which shows that these metals were easily available to vegetables and diffused more in them. Various factors affect the movement of metals which may be climatic or edaphic; the age of the plant is a major influencing agent among these factors (Ahmad et al. 2019).

The efficient transfer of Zn to edible parts of vegetable indicated effective bioaccumulation ability as observed in Nanjing, China (Chao et al. 2007). BCF > 1.0 is indicative of the metal uptake capacity of plants and their
translocation to upper plant tissues; effective transfer and uptake of metals show the presence of efficient systems in plants that enhance metal movement. Metal contents vary in different vegetables and their parts and it could be attributed to the differential ability of plants to uptake metals and movement through root systems (Ugulu et al. 2014).

**Pollution load index of trace metals**

The monitoring of soil quality and its suitability for vegetable cultivation and agricultural use requires the calculation of the severity of pollution in the area of concern, which is calculated as the pollution load index. PLI is one such parameter described by Liu et al. (2005) to examine the extent of pollution in soils in comparison to established reference values. The pollution load index varied between 5.171 (Ni) and 0.061 (Zn). The order of the pollution load indices at three sites, CWI, GWI and MWI, was Ni > Se > Pb > Cd > Mo > As > Co > Cu > Fe > Zn (Table 7).

The maximum PLI was observed for Ni and the minimum PLI was observed for Zn at all treatments. If the PLI value is greater than 1, it means that the food is contaminated and its consumption is risky in terms of health, while a value of less than 1 means that its consumption is safe (Harikumar et al. 2009). In the present study, PLI values for all metals except for Fe, Cu and Zn were higher than 1 and this means that these vegetables cannot be safely consumed. Ashfaq et al. (2015) reported the Cd, Fe, Mn and Cr PLI values as 0.4, 0.01–0.03, 0.01–0.009 and 0.01–0.02, respectively. In addition, Ramteke & Gogate (2016) defined the metal pollution index (MPI) for Fe, Cr, Mn, Cu, Zn and Cd as 4.8, 3.1, 11.0, 15.0, 16.2 and 11.0, respectively. The reason why these values are higher than the values presented in this research may be due to various industrial metal resources, mining and other geochemical mechanisms (Shardendu et al. 2005).

**Enrichment coefficient of trace metals**

The enrichment coefficient was estimated against un-contaminated background levels in soils and vegetable tissues. The enrichment coefficient was the highest for Pb (7.519) at site GWI (Table 8). The same trend of EC was seen for all metals at CWI and GWI treatments, i.e. Pb was followed by Zn, Mo, Cd, Fe, Mo, Cu, As, Ni and Co. A slightly different trend was observed for MWI: Pb > Zn > Cd > Mo > As > Cu > Co > Fe > Zn (Table 7).

The maximum PLI was observed for Ni and the minimum PLI was observed for Zn at all treatments. If the PLI value is greater than 1, it means that the food is contaminated and its consumption is risky in terms of health, while a value of less than 1 means that its consumption is safe (Harikumar et al. 2009). In the present study, PLI values for all metals except for Fe, Cu and Zn were higher than 1 and this means that these vegetables cannot be safely consumed. Ashfaq et al. (2015) reported the Cd, Fe, Mn and Cr PLI values as 0.4, 0.01–0.03, 0.01–0.009 and 0.01–0.02, respectively. In addition, Ramteke & Gogate (2016) defined the metal pollution index (MPI) for Fe, Cr, Mn, Cu, Zn and Cd as 4.8, 3.1, 11.0, 15.0, 16.2 and 11.0, respectively. The reason why these values are higher than the values presented in this research may be due to various industrial metal resources, mining and other geochemical mechanisms (Shardendu et al. 2005).

**Table 6 | Bioconcentration factor between vegetable and soil in L. cylindrica**

| Heavy metal | Mo | As | Se | Fe | Cu | Zn | Ni | Pb | Cd | Co |
|-------------|----|----|----|----|----|----|----|----|----|----|
| CWI         | 1.350 | 0.097 | 0.236 | 6.707 | 4.197 | 12.289 | 0.162 | 0.229 | 1.26 | 0.021 |
| GWI         | 1.2099 | 0.097 | 0.206 | 6.588 | 5.056 | 9.315 | 0.172 | 0.277 | 1.357 | 0.033 |
| MWI         | 1.613 | 0.087 | 0.217 | 6.142 | 5.561 | 12.171 | 0.177 | 0.214 | 1.276 | 0.049 |

**Table 7 | Pollution load index for heavy metals in soil grown with L. cylindrica**

| Heavy metal | Mo | As | Se | Fe | Cu | Zn | Ni | Pb | Cd | Co |
|-------------|----|----|----|----|----|----|----|----|----|----|
| CWI         | 2.106 | 1.342 | 3.817 | 0.103 | 0.448 | 0.061 | 4.755 | 3.410 | 2.162 | 0.949 |
| GWI         | 2.182 | 1.508 | 3.788 | 0.115 | 0.442 | 0.071 | 5.171 | 3.423 | 2.173 | 1.005 |
| MWI         | 1.862 | 1.674 | 3.855 | 0.117 | 0.446 | 0.079 | 5.150 | 3.359 | 2.241 | 0.952 |
Health risk index of trace metals

Uniformity in risk levels was found at three sites for all metals. The health risk index was calculated to assess potential risks posed due to daily intake of metals. Arsenic posed a maximum risk level as its intake was determined at 81.011. The sequence of HRI values examined at CWI, GWI and MWI were As > Cd > Pb > Mo > Cu > Ni > Se > Zn > Fe > Co (Table 9).

Risk levels posed by consumption of luffa vegetable at all study sites were in the range of 81.011 for As to 0.0247 for Co (Table 9). Values of HRI > 1.0 were obtained for As, Mo, Ni, Cu, Cd and Pb; a value greater than 1.0 is an imminent threat to human health (USEPA 2002). Computations by Uboh et al. (2011) revealed lower HRI values for Pb, Cd and higher values for Cu in comparison to the present study. An increase in metal accumulation results in higher HRI values can only be reduced by quality based standardized techniques. The type of plant species and physical/chemical features of the soil significantly influence metal levels in plant tissues and possible health risks.

CONCLUSIONS

The current study has highlighted the risks of using untreated wastewater for irrigation of the commonly consumed vegetable, Luffa cylindrica. The entry of hazardous and toxic metals into the food chain, which culminates in humans being the final consumers, indicates high-risk levels.

In the present study, PLI values for all metals except for Fe, Cu and Zn were higher than 1. This means that these vegetables cannot be safely consumed. The reason for the higher values presented in this research may be due to various industrial metal resources, mining and other geochemical mechanisms. Also, values of HRI > 1.0 were obtained for As, Mo, Ni, Cu, Cd and Pb; these values are an important threat to human health. In line with this study and especially the relevant health risk index values, the government and civil society organizations should take measures to effectively regulate and monitor the discharge of wastewater into common water sources used for agricultural purposes.

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Table 8 | Enrichment coefficient of heavy metals in L. cylindrica from soil to edible parts of vegetable

| Heavy metal | Site | Mo | As | Fe | Cu | Zn | Ni | Pb | Cd | Co |
|-------------|------|----|----|----|----|----|----|----|----|----|
| CWI         |      | 0.810 | 0.402 | 0.898 | 0.482 | 5.431 | 0.022 | 6.222 | 3.757 | 0.004 |
| GWI         |      | 0.726 | 0.400 | 0.882 | 0.579 | 4.116 | 0.023 | 7.519 | 4.044 | 0.006 |
| MWI         |      | 0.968 | 0.360 | 0.822 | 0.639 | 5.379 | 0.024 | 5.810 | 3.801 | 0.009 |

Table 9 | Health risk index of heavy metals due consumption of L. cylindrica from different sites

| Heavy metal | Site | Mo | As | Se | Fe | Cu | Zn | Ni | Pb | Cd | Co |
|-------------|------|----|----|----|----|----|----|----|----|----|----|
| CWI         |      | 5.449 | 72.45 | 0.726 | 0.322 | 2.266 | 0.511 | 2.0024 | 10.457 | 23.355 | 0.0247 |
| GWI         |      | 5.0589 | 81.011 | 0.627 | 0.356 | 2.684 | 0.451 | 2.320 | 12.686 | 25.271 | 0.0403 |
| MWI         |      | 5.758 | 80.915 | 0.673 | 0.336 | 2.994 | 0.661 | 2.370 | 9.619 | 24.485 | 0.056 |
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