Original article

Potential health risks assessment cognate with selected heavy metals contents in some vegetables grown with four different irrigation sources near Lahore, Pakistan

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A B S T R A C T
Carcinogenic and health hazard causing heavy metals have been increasing in our dietary stuffs due to large amount of industrial effluents being dumped in water bodies that are ultimately used for irrigation purposes. The study was aimed to assess and compare the mean concentrations of heavy metals (Cd, As and Pb) in soil and vegetables irrigated with four different sources (Ground water, river water, domestic sewage water and industrial untreated effluents and domestic waste water receiving drains) for the estimation of carcinogenic and non-carcinogenic health risk associated with them. Prepared samples were analyzed by through ICP-OES. Statistical analysis revealed that domestic sewage water and drains water usage for irrigation purposes leads to high values of Estimated Daily Intake (EDI) of metals through vegetation. To assess the carcinogenic effects values daily intakes, Total hazard quotients (THQs) and Health indexes (HI), while for carcinogenic effects, Total cancer risks (TCR) were determined. The results of present study revealed that the daily intakes of these metals are far less than that of permissible levels but their bio-accumulating behavior produce high risks to human health. The HI values revealed that waste water usage is producing the vegetables of high health risks. In adults, the HI of Phaseolus vulgaris, Spinacia oleracea, Brassica campestris, Raphanus sativus, Daucus carota and Solanum tuberosum assessed as 0.81, 1.52, 1.26, 0.12, 0.22, and 0.15 (ground water irrigation), 0.046, 0.75, 0.51, 0.68, 0.90 0.064 (River Ravi water irrigation), 1.23, 3.34, 4.81, 4.23, 1.41 and 3.43 (domestic sewage irrigation) and 3.04, 5.50, 6.08, 2.50, 5.34 and 5.13 (Drain waste water irrigation), respectively. It was observed that cancer risks of As exceeded the threshold (1 × 10−4) in all i.e. ground river, domestic sewage and drain water grown vegetables, while, Cd and Pb were in permissible range.

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1. Introduction

Human health always remained a major issue in highly populated countries. Heavy industrialization leads to abundant consumption of ground water resources. In turn, wastewater is the cheaper source for irrigation of lands. Under developing countries also facing the problems of electric power generation, so like other under developing country Pakistan also face problem of high electricity prices which leads to enforce the agriculture farmers to utilized the wastewaters for irrigation. There are some common practices for irrigation are used individually and in some areas working together to cover the need of water for irrigation. The use of waste water for irrigation purpose, troubling the human
health (Alturiqi et al., 2020), because waste water not only increase the load of bacteria, fungi, parasitic protozoans and essential trace elements (Ohoro et al., 2019), but it may also enhance the toxic non-essential trace elements to soils where the plants are going to be grown. As, Cd and Pb are non-essential heavy metals that are entering in our food chains through soils (Margenat et al., 2019; Khalid et al., 2017). Among all cotaminants heavy metals have gained more interest due to their persistant, bioaccumulating and biomagnifying nature (Zakaria et al., 2021; Pandiyan et al., 2021). Heavy metals increases the oxidative stress by enhancing the reactive oxygen species (ROS) in aerobic cells (Orun et al., 2008).

Heavy metals cause serious carcinogenic and noncarcinogenic effects in body i.e. at low level ingestion of arsenic may cause non-carcinogenic effects like sore throat and irritated lungs, nausea, vomiting, darkening of skin lesions and warts (Signes-Pastor et al., 216)). Furthermore, its chronic intake may lead to neurobehavioral and neuropathic alterations, loss of memory, lowering of IQ level, perceptive and motor damage skeltal system by distrubing the metabolism of Ca, Zn, Cu, and Fe (Kim et al., 2015) but it may also can play a role initial role in cancer forming in breasts, pancreas, lungs, prostate, kidneys, nasophyrnx and testicles (Genchii et al. 2020). Similarly, Lead(Pb) cause the neurotoxicity in adult and childrens. Mainly, Pb affect the brain, kidney, liver and reproductive system (Brewer et al., 2020). It may cause the lowering of IQ level, perception power. It may also made the hyperactivity of nervous system (Fu and Xi, 2020). In addition, Pb burden in blood cause bladder cancer (Awadalla et al., 2020).

In current situations of hilghly populated Lahore it is very necessary to assess the contaminantion levels of food and its associated health risks. This research is mainly, aimed to study the the toxicity level of heavy metals in soil and vegetables, estimated daily intakes heavy metals, total hazard quotients, hazard indexs and TCRs in vegetables and blank samples were done by following the optimizied method as described (Gebeeyehu and Bayissa, 2020). Added 9 ml HNO3 and 3 ml HCl at digestion time of 45 min on hot plates at 180 °C in 1 g dried samples. Blank samples were also prepared by following optimum conditions.

2.2. Approach for sampling

Samples of human edible parts of vegetables along with their related and soil samples were collected from each type of land classified on the basis of water source for irrigation. Samples of survey based highly consumed vegetables Spinacia alicerata, Brassaica compestris, Raphanus sativus, Phaseolus vulgaris, Daucus carota and Solanum tuberosum were collected from each source of irrigation by following the APHA, (2012).

2.3. Sampling and preparation

2.3.1. Soil

Soil samples were mechanically ground, sieved properly and stored for further processing. 1 g of each soil samples were mixed with 10 ml HNO3, heated on hot plate to 95 °C for 10 min and then cool down. After cooling, added 5 ml HNO3 and refluxed for 30 min till brown fumes aroused from digesting samples. We added 5 ml HNO3 in repetition untill brown fumes ended after this we added 3 ml of H2O2 to make all possible oxidation process completed. In the last added 10 ml HCl and again heated for 30 min to accomplish the digestion as described by Kacholi and Sahu, (2018).

2.3.2. Vegetables samples preparation

Plant’s edible parts samples were collected separately. All the stucc dust particles were removed by washing with de-ionized distilled water. After oven drying at 70–80 °C for 24–48 h all the samples were crumbled to make fine powder. Digestions of all the vegetables and blank samples were done by following the optimized method as described Gebeeyehu and Bayissa, (2020). Added 9 ml HNO3 and 3 ml HCl at digestion time of 45 min on hot plates at 180 °C in 1 g dried samples. Blank samples were also prepared by following optimum conditions.

2.4. Heavy metal analysis

After digestion all the, soil and plants digested samples were diluted up to 50 ml in volumetric flask with 2% HNO3 and then filtered by using whatman filter paper No. 42 into 50 ml vacuumed volumetric flask. All the samples were analyzed for heavy metals by using inductively coupled plasma optical plasma emission spectrometry (ICP-OES). After every three-sample analysis, blank samples were run to ensure the correct measurement by the machine. The correctness each metal’s analysis was checked using standard reference solutions of each metal.

2.5. Bioaccumulation factors (BAFs)

This factor determined the bio-availability of heavy metals to plants from soil. BAFs were calculated by using the following equation.

\[
BAF = \frac{C_p}{C_s}
\]

where Cp and Cs stand for the heavy metal concentration in plants and soil respectively.

2.6. Health risk assessment

2.6.1. Estimated daily intake (EDI)

The daily intake of metals depends on rate of daily food consumption. By using the following equation (2), the estimated daily intake of metals are calculated.
where $E_f$ represented the exposure frequency (365 days of whole year), $E_D$ denoted the exposure duration (70 years), $C_m$ represented the concentration of metals (mg/g), $C_f$ stands for conversion factor from wet to dry weight of vegetable, which is 0.085 as proposed by (Rattan et al., 2005), $I_{IR}$ is ingestion rate of vegetable which is 0.345Kg for adult and 0.232Kg for children (Yaacob et al., 2018), $Bw$ is average body weight (70Kg) and $A_T$ is average time (365 day / 70 years) as reported by Antoinie et al., (2017).

2.6.2. Target hazard quotient (THQ)

Different biomagnifying contaminants had caused carcinogenic and non-carcinogenic effects in our body. Target Health Quotients is the parameter which is considered to assess the non-carcinogenic effects as described by Ezemonye et al., (2019) and Agoro et al., (2020). THQs can be calculated by the following equation (3).

$$THQ = \frac{EDI}{RfD}$$

where $EDI$ is estimated daily intake of metal (mg/day/Kg) and $RfD$ is Oral Reference dose of heavy metal. Values of $RfD$ of As, Cd and Pb are presented in Table 1. It is presumed that if THQ value is greater than 1 then body definitely show non-carcinogenic effects. But if it remained less than the limit (1) then it is considered to be negligible chances of non-carcinogenic effects in human body.

2.6.3. Hazard Index:

The cumulative noncarcinogenic effects of all heavy metals coming through a particular vegetable is evaluated by the Hazard index equation as described by Gebeyehu and Bayissa (2020).

$$HI = \sum_{i=1}^{n} THQ_i; i = 1, 2, 3 \ldots , n$$

2.6.4. Cancer risk

Cancer risk is a unit less probability of getting cancer. It may be measured by the following equation (4) as described by Liang et al., (2017).

$$CR = EDIxCPSo$$

where $EDI$ is estimated daily intake of metal and $CPSo$ is the oral slope factor.

The oral cancer slope factor is the tool which converts the average daily intake of contaminant into gradual risk of developing cancer with life time exposure. All the details of $CPSo$ of As, Cd and Pb are presented in Table 1.

2.7. Statistical analysis

To calculate the means and Standard deviation of replicates of soil and vegetable sample’s data were calculated with the help of statistical analysis system (SAS).

3. Results

The demand of organic food has also been increased many times due to over population in recent few decades. Because of very high demands of pure and organic food, some farmers are using waste water without any discrimination to irrigate their fields. Overall, effect of such contaminations may cause many risks human health. So it is very necessary to measure and compare the level of contamination done by each irrigating sources used in Lahore.

3.1. Mean concentration of heavy metals in soils

Table 1 Constant parameters used in calculation of THQ and Cancer risk.

| Parameters            | Metals | Reference dose | Reference                  |
|-----------------------|--------|----------------|----------------------------|
| Oral Reference dose   | As     | 0.0003         | (Antoine et al., 2017)     |
|                       | Cd     | 0.001          | (Antoine et al., 2017)     |
|                       | Pb     | 0.0035         | (Rai et al., 2019)         |
| Oral Cancer Slope factors | As    | 1.5            | (Antoine et al., 2017)     |
|                       | Cd     | 0.38           | (Yang et al., 2018)        |
|                       | Pb     | 0.0085         | (Yang et al., 2018)        |
Compared to green bean, spinach, and mustard, radish and green beans showed the lowest contamination levels of As, Cd, and Pb. The table below shows the mean concentrations (mg Kg$^{-1}$) ± S.D. of selected heavy metals in soil of some vegetable fields treated with four different irrigation systems.

### Table 2

| Fields of vegetables | HMs | GWI | RWI | Dom.WWI | Dr.WWI |
|----------------------|-----|-----|-----|---------|--------|
| Phaleorus vulgaris    | As  | 4.86±0.17 | 5.58±0.46 | 6.78±0.06 | 14.73±0.21 |
| (Green bean)         | Cd  | 3.29±0.24 | 3.61±0.03 | 5.10±0.88 | 6.61±0.07 |
|                      | Pb  | 3.56±0.11 | 4.78±0.12 | 4.78±0.12 | 12.58±0.16 |
| Spinacia oleracea    | As  | 6.39±0.21 | 9.21±1.59 | 10.12±0.01 | 13.82±0.58 |
| (Spinach)            | Cd  | 1.33±0.05 | 3.06±0.02 | 3.24±0.33 | 3.81±0.04 |
|                      | Pb  | 4.35±0.02 | 7.84±0.05 | 9.60±0.07 | 10.32±0.29 |
| Brassica compestris  | As  | 3.17±0.43 | 3.87±0.05 | 14.38±2.57 | 12.55±0.17 |
| (Mustard)            | Cd  | 3.46±0.21 | 3.44±0.33 | 5.44±0.33 | 8.56±0.28 |
|                      | Pb  | 4.23±0.11 | 6.66±0.17 | 10.33±0.26 | 13.36±0.40 |
| Raphanus sativus     | As  | 3.34±0.51 | 5.86±0.11 | 17.51±3.09 | 19.19±0.27 |
| (Radish)             | Cd  | 3.36±0.03 | 2.57±0.05 | 5.57±0.04 | 9.11±0.03 |
|                      | Pb  | 4.30±0.10 | 6.10±0.44 | 11.99±0.99 | 12.58±0.23 |
| Daucus carota        | As  | 2.69±0.61 | 4.91±0.07 | 6.41±0.16 | 14.26±0.04 |
| (Carrot)             | Cd  | 2.53±0.02 | 3.99±0.02 | 3.99±0.02 | 7.32±0.06 |
|                      | Pb  | 2.41±0.03 | 3.75±0.08 | 10.89±0.07 | 15.45±0.11 |
| Solanum tuberosum    | As  | 2.36±0.10 | 4.19±0.15 | 10.48±0.08 | 114.28±0.12 |
| (Potato)             | Cd  | 1.27±0.12 | 3.85±0.06 | 3.57±0.19 | 2.61±0.35 |
|                      | Pb  | 3.22±0.01 | 5.09±0.01 | 11.88±0.33 | 10.40±0.01 |

### 3.2. Mean concentration of heavy metals in vegetables

The mean concentrations of As ranged from 0.073 mg Kg$^{-1}$ (S. tuberosum), 0.194 mg Kg$^{-1}$ (B. compestris), 0.477 mg Kg$^{-1}$ (P. vulgaris) and 1.5 mg Kg$^{-1}$ (R. sativus) to 1.07 mg Kg$^{-1}$ (S. oleracea), 0.59 mg Kg$^{-1}$ (D. carota), 3.038 mg Kg$^{-1}$ (B. compestris) and 3.50 mg Kg$^{-1}$ (S. oleracea) irrigated with ground water, river Ravi water, domestic sewage water and effluent receiving drains water, respectively. Similarly, the mean concentrations of Cd were recorded lowest as 0.008 mg Kg$^{-1}$ (S. tuberosum), 0.014 mg Kg$^{-1}$ (S. tuberosum), 0.149 mg Kg$^{-1}$ (R. sativus and), 0.149 mg Kg$^{-1}$ (R. sativus) and highest as 0.07 mg Kg$^{-1}$ (B. compestris), 0.143 mg Kg$^{-1}$ (B. compestris), 0.828 mg Kg$^{-1}$ (P. vulgaris) and 0.944 (B. compestris) grown with ground water, river Ravi water, domestic sewage water and drains water, respectively. While, range of Pb were observed as 0.003 (D. carota), 0.75 mg Kg$^{-1}$ (S. oleracea), 0.15 (R. sativus)-1.51 mg Kg$^{-1}$ (D. carota), 1.06 (R. sativus)-3.39 (B. compestris) and 2.86 (R. sativus)-7.83 (B. compestris) irrigated with ground water, river water, domestic sewage water and drains water respectively. All the details of mean concentration of heavy metals in vegetables were presented in Table 3.

### 3.3. Biaccumulation factors (BAFs)

BAFs investigation is helpful tool to compare the accumulation tendencies of the different plant. Fig. 2 represented that percentage BAF of heavy metal in some vegetables. The result of this study indicated that ranking of accumulation factor of Pb under GWI B. Compestris > S. oleracea > P. vulgaris > S. tubersum > R. sativus > D. carota. Whereas, under RWI Pb accumulation ranked as B. compestris > S. oleracea > S. tubersum > P. vulgaris D. carota > R. sativus. While, with domestic WWI Pb BAFs were ranked as B. compestris > S. oleracea > S. tubersum P. vulgaris = D. carota > R. sativus. However, BAF of Pb under drain WWI ranked as B. compestris > S. oleracea > P. vulgaris = D. carota > S. tubersum > R. sativus.

BAFs for As in vegetables treated with GWI, RWI, domestic WWI and drain WWI were observed in decreasing order as B. compestris > S. oleracea > P. vulgaris > D. carota > S. tubersum > R. sativus, B. compestris > S. oleracea > S. tubersum > P. vulgaris > R. sativus > D. carota, B. compestris > S. oleracea > S. tubersum > R. sativus > D. carota > P. vulgaris and B. compestris > S. oleracea > D. carota = S. tubersum > P. vulgaris > R. sativus respectively.

BAFs of Cd were ranked as B. compestris > S. oleracea > P. vulgaris > D. carota > S. tubersum > R. sativus, B. compestris > S. oleracea > S. tubersum > P. vulgaris > R. sativus > D. carota, B. compestris > S. tubersum = D. carota > S. tubersum > P. vulgaris and B. compestris > S. oleracea > D. carota = S. tubersum > P. vulgaris > R. sativus under irrigation with GWI, RWI, domestic WWI and drain WWI, respectively. Fig. 2. (2a) BAFs of Pb in GWI vegetables, (2b) BAFs of Pb in RWI vegetables, (2c) BAFs of Pb in DomWWI vegetables, (2d) BAFs of Pb in DrWWI vegetables, (2e) BAFs of As in GWI vegetables, (2f) BAFs of As in RWI vegetables, (2g) BAFs of As in DomWWI vegetables, (2h) BAFs of As in DrWWI vegetables, (3I) BAFs of Cd in GWI vegetables, (2j) BAFs of Cd in RWI vegetables, (2k) BAFs of Cd in DomWWI vegetables, (2l) BAFs of Cd in DrWWI vegetables.

### 3.4. Health risk assessment

#### 3.4.1. Estimated daily intakes (EDI) of heavy metals

Estimated daily intakes (EDI) in terms of mg/Kg/day were calculated for the child and adult separately by using equation (2) and computations were shown in Figs. 3(a) and (3b) respectively.

In adults, the consumption of S. oleracea gives the lowest and highest EDI of As, Cd and Pb were observed as 1.63 × 10$^{-3}$ (RWI) and 1.47 × 10$^{-3}$ (DrWWI), 9.6 × 10$^{-6}$ (GWI) and 1.71 × 10$^{-4}$ (DrWWI), 3.16 × 10$^{-6}$ (GWI) and 1.53 × 10$^{-3}$ (DrWWI) under different irrigation sources respectively. While, through S. oleracea consumption, EDI for As, Cd and Pb to children ranged as 2.39 × 10$^{-4}$ (RWI)-1.47 × 10$^{-3}$ (DrWWI), 1.42 × 10$^{-5}$ (GWI)-1.7 × 10$^{-3}$ (DrWWI) and 4.65 × 10$^{-4}$ (GWI)-1.5 × 10$^{-3}$ (DrWWI) respectively. In adults, B. compestris consumption EDI of As, Cd and Pb varied from 8.13 × 10$^{-5}$(RWI), 2.93 × 10$^{-5}$(GWI) and 3.12 × 10$^{-4}$ (GWI) to 1.42 × 10$^{-2}$ (DrWWI), 3.95 × 10$^{-4}$ (DrWWI)
and \(3.28 \times 10^{-3}\) (DrWWI), among four different sources of irrigation respectively. While, the utilization of *B. compestris* by child, EDI of As ranged from \(1.20 \times 10^{-4}\) (RWI) to \(1.87 \times 10^{-3}\) (DomWWI), Cd varied from \(4.31 \times 10^{-5}\) (GWI) to \(3.95 \times 10^{-4}\) (DrWWI) and Pb ranged from \(4.58 \times 10^{-4}\) to \(3.28 \times 10^{-3}\) (Dr.WWI).

Lowest EDI of As, Cd and Pb were observed in ground water irrigated *R. sativus* as \(3.06 \times 10^{-5}\), \(9.60 \times 10^{-6}\) and \(3.60 \times 10^{-5}\) respectively. While highest EDI of As, Cd and Pb were recoded in waste water of drain water irrigated *R. sativus* \(1.20 \times 10^{-4}\) (RWI) to \(1.87 \times 10^{-3}\) (DomWWI) and Pb ranged from \(4.58 \times 10^{-4}\) to \(3.28 \times 10^{-3}\) (Dr.WWI).

In adults and childrens the EDI of heavy metals due to consumption of *S. oleracea*, have followed the decreasing order as As > Pb > Cd, Pb > As > Cd, As > Pb > Cd, and Pb > As > Cd under GW, RW, DomWW and Dr.WW irrigation, respectively. The EDI of corresponding heavy metals through ingestion of *B. compestris* ranked in the decreasing order as As > Pb > Cd, Pb > As > Cd, Pb > As > Cd, and Pb > As > Cd under GW, RW, DomWW and Dr.WW irrigation, respectively. Similarly, ingestion of *R. sativus* may incorporated these metals in the decreasing order as Pb > As > Cd, As > Pb > Cd, and Pb > As > Cd under GW, RW, DomWW and Dr WW irrigation, respectively. The EDI of As, Cd and Pb due to ingestion of *D. carota* showed trend in the decreasing...
order as As > Cd > Pb, As > Pb > Cd, Pb > As > Cd, and Pb > As > Cd under GW, RW, DomWW and DrWW irrigation, respectively. However, the consumption of S. tuberosum and P. vulgaris both showed similar trends in the decreasing order as Pb > As > Cd, Pb > As > Cd, Pb > As > Cd and Pb > As > Cd under GW, RW DomWW, and DrWW irrigation, respectively, in adult and child. All the comparisons are presented in Figs. 3a and 3b.

3.4.2. Target hazard quotient (THQ)

To study the carcinogenic effects, total hazard quotients are investigated. The data of THQs for child and adult obtained by using Equation (3) is presented in Figs. 4a and 4b respectively. THQ of As under GWI has been found in the range of 0.10 (R. sativus = S. tuberosum) to 1.42 (S. oleracea). The corresponding value of THQ of under GWI varied from 0.003 (S. tuberosum) to 0.026 (P. vulgaris), while, the range of Pb in the same treatment assessed as 0.00 to 0.09 in S. tuberosum and S. oleracea, respectively. THQ of As, Cd and Pb in vegetables grown on RWI showed the variation from 0.27 (B. compestris), 0.01 (S. tuberosum), 0.02 (R. sativus) to 0.82 (D. carota), 0.05 (B. compestris) and 0.18 (S. oleracea and B. compestris), respectively.

The results indicated that vegetables cultivated under Dom. WWI has higher THQs than GWI and RWI vegetables, but less than Dr.WWI vegetables. THQ of As, Cd and Pb in Dom.WWI vegetables varied from 0.67 (P. vulgaris), 0.06 (R. sativus) and 0.13 (R. sativus) to 4.24 (B. compestris), 0.35 (P. vulgaris) and 0.41 (B. compestris), respectively.
Fig. 3b. Estimated daily intake of selected heavy metals to human adults from some vegetables raised with different irrigation systems.

Fig. 4a. Target hazard quotient of selected heavy metals to human children from some vegetables raised with different irrigation systems.

Fig. 4b. Target hazard quotient of selected heavy metals to human adults from some vegetables raised with different irrigation systems.
respectively. However, THQ of AS, Cdd and Pb got highest ranges of 2.09 (R. sativus)-4.89 (S. oleracea), 0.06 (R. sativus)-0.40 (B. compestris) and 0.34 (R. sativus) if they were grown under Dr.WWI.

In case of child the values of THQs of As, noticed greater than threshold (1) and are ranked in decreasing order as 4.89 (S. oleracea) > 4.75 (B. compestris) > 4.55 (S. tuberosum) > 4.54 (D. carota) > 2.33 (P. vulgaris) and 2.09 (R. sativus) under Dr.WWI vegetables. While, As also crossed the limit (1) for THQs in consumption of river water is also not safe to childrens. It was noticed that con-
near to cross the limit value as 0.98.

OTA grown with Dr.WWI.

very alarming condition to consume such vegetables especially, vlues of As of THQs transcend far away than limited value, which is in childrens with more alarming values. It has been observed that value except Wl all vegetables also showed exceeded value than the limited value (1). Corresponding THQs values for Arsenic under Dom.

Cd. As in all vegetables under Dr.WWI and exceeded than the limited value (1). Corresponding THQs values for Arsenic under Dom. WWI all vegetables also showed exceeded value than the limited value except P. vulgaris. The same pattern of THQs is also recorded in childrens with more alarming values. It has been observed that values of As of THQs transcend far away than limited value, which is very alarming condition to consume such vegetables especially, grown with Dr.WWI.

3.4.3. Hazard index (HI)

The collective effect of all heavy metals is evaluated by the Hazard index. HI for each vegetable is computed by using Equation (4) and the results are indicated in Figs. 5a and 5b for child and adult respectively. HI investigation revealed that under GWI individual contribution of of S. oleracea (37%) followed by B. compestris (31%), P. vulgaris (20%), D. carota (5%), S. tuberosum (4%) and R. sativus (3%) was recorded. It has been further noticed that under this irrigation S. oleracea and B. compestris exceeded the threshold level. Similarly, RWI irrigated vegetables also made their part to overall cumulative effect in decreasing order as D. carota (23%) > S. oleracea (19%) > R. sativus (17%) > S. tuberosum (16%) > B. compestris (13%) > P. vulgaris (12%). While, under domestic wastewater irrigation B. compestris (26%), R. sativus (23%), S. tuberosum (18%), S. oleracea (18%), D. carota (8%) and P. vulgaris (7%) ranked according to per-
centage participation. However, contribution of vegetables grown on DRWW were measured as in the decreasing order as R. sativus (9%) < P. vulgaris (11%) < S. tuberosum (19%) = D. carota (19%) < S. oleracea (20%) < B. compestris (22%). Due to DomWW and DrWW irrigation, all selected vegetables were exceeded the threshold.

Where, 5a(i), 5a(ii), 5a(iii), and 5a(iv) showed the HI of some vegetables to children grown with ground GWI, RWI, DomWWI and DrWWI respectively.

Where, 5b(i), 5b(ii), 5b(iii), and 5b(iv) showed the HI of some vegetables to adults grown with ground GWI, RWI, DomWWI and DrWWI respectively.

3.4.4. Carcinogenic risk assessment (CR)

The consumption of heavy metal contaminated dietary stuff for long term exposure throughout the life on daily basis, considered to be carcinogenic effects (Cancer in different parts of body). United States Environmental Protection Agency, 2011 stated that if cancer risk values lie between 10^-6 to 10^-4, it causes tolerable risk but if it is less than 10^-6 it can be ignored while, CR values more than 10^-4 is unacceptable. It has been determined that almost all vegetables under all irrigation system only Arsenic’s CR had surpassed the limit (1.0x10^-4). The results of CR for children and adults have been calculated by using equation5 and were presented in Table 4.

4. Discussion

Source of irrigation had a great impact on bioavailability of heavy metals to plants. In the present study effects of irrigation system on bioavailability of heavy metal were assessed to compare the levels of risks associated with irrigation system.

4.1. Levels of heavy metals in soil

To assess the health risk it is necessary to determine the levels of heavy metals in soil where the vegetables are to be grown. Because solid and liquid waste management and waste dumping had increase the levels of heavy metals in soil (Zhuang et al., 2009). Soils polluted with heavy metals augement the more metallic ions uptake in plants (Wei et al., 2021; Guerra Sierra et al., 2021).

![Fig. 5a](image)

Hazard index of heavy metal contaminated vegetables to human children from some vegetables raised with different irrigation systems.
The result of current study showed that level of As and Pb remained under the permissible limit of Indian standards Awasthi, (2000), FAO/WHO (2001) and Union standards, (2006) as reported by Mahmood and Malik (2014). But Cd exceeded in soils where vegetables were grown with drain WWI. Similar findings of Mahfooz et al., (2020) also confirm that bioavailability of metals had increased by irrigating the vegetable and crops with wastewater.

### 4.2. Levels of heavy metals (mg Kg⁻¹) in vegetables

The results of the present investigation were compared with maximum permissible levels (MPL) given by authorities as presented in Table 3. It has been assessed that all vegetables have been contaminated by As, Cd and Pb under RWI, DomWWI and DrWWI, except GW irrigated vegetables where they showed partial contamination. The mean concentration of heavy metals in GW irrigated vegetables remained less than maximum permissible level (MPL) as recommended by FAO/WHO (2014). The reasons of lower amounts of these metals under ground water irrigation may be that heavy metals leached down to deeper layer and distributed in few meters depth soil (Singh et al. 2010). The comparisons of results of this study with background values indicated that groundwater has less effect on bioaccumulation in plants than wastewater usage for irrigation (Mahmood and Malik 2014). Likuku and Obuseng, (2015) reported that Pb in Capsicum annum (green pepper) and Solanum lycopersicum (tomatoes) grown with ground water bioaccumulated in lesser concentrations than in correspond-

### Table 3

Comparisons of mean concentrations (mg Kg⁻¹) ± s.d of selected heavy metals in some vegetable’s consumable parts grown under four different irrigation systems.

| Plants names   | HMs      | GWI Means ± SDs | RWI Means ± SDs | Dom.WWI Means ± SDs | Dr.WWI Means ± SDs | Standards          |
|---------------|----------|----------------|-----------------|---------------------|-------------------|-------------------|
| Grain         |          |                |                 |                     |                   |                   |
| Phaseolus vulgaris (Green bean) | As       | 0.51 ± 0.118   | 0.243 ± 0.108   | 0.477 ± 0.016       | 1.67 ± 0.170      | 0.2 a             |
|               | Cd       | 0.063 ± 0.034  | 0.086 ± 0.011   | 0.828 ± 0.059       | 0.435 ± 0.174     | 0.05 b            |
|               | Pb       | 0.585 ± 0.097  | 0.676 ± 0.112   | 1.845 ± 0.140       | 4.433 ± 0.515     | 0.1 b             |
| Leafy         |          |                |                 |                     |                   |                   |
| Spinacea oleracea (Spinach) | As       | 1.017 ± 0.004  | 0.388 ± 0.155   | 2.151 ± 0.240       | 3.50 ± 1.210      | 0.2 a             |
|               | Cd       | 0.023 ± 0.012  | 0.058 ± 0.021   | 0.187 ± 0.139       | 0.409 ± 0.236     | 0.05 b            |
|               | Pb       | 0.754 ± 0.071  | 1.50 ± 0.405    | 2.121 ± 0.455       | 3.664 ± 0.988     | 0.3 b             |
| Brassica compestis (Mustard) | As       | 0.821 ± 0.126  | 0.194 ± 0.08    | 3.038 ± 0.534       | 3.40 ± 0.01       | 0.2 a             |
|               | Cd       | 0.07 ± 0.020   | 0.143 ± 0.157   | 0.381 ± 0.206       | 0.944 ± 0.124     | 0.05 b            |
|               | Pb       | 0.744 ± 0.169  | 1.51 ± 0.435    | 3.389 ± 0.214       | 7.83 ± 0.623      | 0.3 b             |
| Roots         |          |                |                 |                     |                   |                   |
| Raphanus sativus (Radish) | As       | 0.073 ± 0.035  | 0.45 ± 0.380    | 2.891 ± 0.297       | 1.501 ± 0.440     | 0.2 a             |
|               | Cd       | 0.023 ± 0.005  | 0.086 ± 0.065   | 0.149 ± 0.173       | 0.149 ± 0.172     | 0.05 b            |
|               | Pb       | 0.086 ± 0.006  | 0.155 ± 0.125   | 1.065 ± 0.015       | 2.858 ± 0.382     | 0.1 b             |
| Daucus carota (Carrot) | As       | 0.148 ± 0.043  | 0.59 ± 0.136    | 0.781 ± 0.067       | 3.25 ± 0.170      | 0.2 a             |
|               | Cd       | 0.041 ± 0.022  | 0.056 ± 0.039   | 0.246 ± 0.382       | 0.336 ± 0.165     | 0.05 b            |
|               | Pb       | 0.003 ± 0.00   | 0.472 ± 0.049   | 1.841 ± 0.061       | 5.543 ± 0.288     | 0.1 b             |
| Stem tuber    |          |                |                 |                     |                   |                   |
| Solanum tuberosum (Potato) | As       | 0.073 ± 0.013  | 0.385 ± 0.036   | 2.147 ± 0.056       | 3.26 ± 1.270      | 0.2 a             |
|               | Cd       | 0.008 ± 0.000  | 0.014 ± 0.000   | 0.28 ± 0.081        | 0.233 ± 0.089     | 0.05 b            |
|               | Pb       | 0.332 ± 0.013  | 0.773 ± 0.089   | 2.591 ± 0.216       | 3.998 ± 0.096     | 0.1 b             |

(a) Codex Alimentarius Commission. Joint FAO/WHO food standards program, 2014.
(b) FAO/WHO, 2014.

Fig. 5b. Hazard index of heavy metal contaminated vegetables to human adults from some vegetables raised with different irrigation systems.
ing vegetable grown with waste water. It has also been assessed that uptake of metal concentration in vegetables grown with DrWW remained highest followed by DomWW, RW water and GW. The highest uptake in drain irrigated vegetables may be due to dischargeing the traffic emission, discharge from Pb storage batteries, lots of textile mills, paint industries and tanneries in the vicinity of Lahore. Gebeyehu and Bayissa (2020) indicated that As and Pb exceeded the threshold, while, the Pb and Cd under the same irrigation system remained lower than threshold in all vegetables. However, 33.33% GW vegetables surpassed the limit (1) of THQ only for As. While, under RWI no heavy metal showed higher THQ than threshold level. It was concluded that As and Cd is the metal which has higher risks for non-carcinogenic effects than Pb and Cd. It has also been concluded that DomWW and DrWW systems are threatening the human health. Higher THQs enhance the danger for the children because values of THQs become double for childrens. Many studies had also similar finding to this study. Gebeyehu and Bayissa, (2020) indicated that As and Hg found to be greater than unity in tomato and As, Hg and Co also found to be $> 1$ in cabbage. Ametepey et al., (2018) find that THQs for Cd and Cr surpassed the threshold level but others remained in safer limits. However, Meng et al., 2021 observed that Cd and Pb

### 4.4. Health risk assessment

#### 4.4.1. Estimated daily intake (EDI) of heavy metals from dietary stuffs

The values of EDI of heavy metals recorded during this investigation has been found far lower than Maximum Tolerable Daily Intake doses (MTDI). MTDI of As, Pb, and Cd were reported by Shaheen et al., (2016) and Gebeyehu and Bayissa, (2020) as 0.13 mg/day, 0.21 mg/day and 0.07 mg/day respectively. These values of MTDI like this study were also compared with their data by Haque et al., (2021), Gebeyehu and Bayissa, (2020), and they observed the similar results to present study. Previous investigations as this study revealed that EDI of heavy metals was lower than the MTDI but their accumulating nature in living organisms can cause various carcinogenic and non carcinogenic effects in body. So calculations of EDI is very useful tool for the assessment target hazard quotients, health index and cancer risks.

#### 4.4.2. Target hazard quotient

It is considered that if $THQ > 1$ then carcinogenic effects will be observed in body, but if it remained less than 1 then there will be no noncarcinogenic effects in human body. In present study, THQ of As for adult, 100% and 83.3% vegetables under DrWWI and DomWWI exceeded the threshold, while, the Pb and Cd under the same irrigation system remained lower than threshold in all vegetables. However, 33.33% GW vegetables surpassed the limit (1) of THQ only for As. While, under RWI no heavy metal showed higher THQ than threshold level. Finally, it was concluded that As is the metal which has higher risks for non-carcinogenic effects than Pb and Cd. It has also been concluded that DomWW and DrWWI systems are threatening the human health. Higher THQs enhance the danger for the childrens because values of THQs become double for childrens. Many studies had also similar finding to this study. Gebeyehu and Bayissa, (2020) indicated that As and Hg found to be greater than unity in tomato and As, Hg and Co also found to be $> 1$ in cabbage. Ametepey et al., (2018) find that THQs for Cd and Cr surpassed the threshold level but others remained in safer limits. However, Meng et al., 2021 observed that Cd and Pb

### 4.3. Bioaccumulation factors (BAFs)

The main root of entry of persistent contaminants in food chain is the uptake of these contaminants from soil to plants. The ratio of uptake of heavy metals to plants from soil is known as bioaccumulation facor. There are various factors which can play their role in variation of bioaccumulation factors e.g. source of irrigating water, physico-chemical condition of water and soil, type of plant, type and concentration of heavy metal in water and soil (Sharma et. al., 2018; Gao et al., 2018). It has been assessed that leafy vegetables have higher BAFs than fruits and root vegetables. The similar finding was also reported by Hu et al., (2017a), Gebeyehu and Bayissa, (2020) and Meng et al., (2021). Furthermore, they also indicate that leafy vegetables had higher potential health risk than root, stem tuber and fruity vegetable. The values of BAFs of present study indicated that use of wastewater leads to higher bioavailability to plants than groundwater irrigation. Because vegetables grown with wastewater had higher heavy metal concentrations as compared to groundwater irrigated vegetables (Mahmood and malik, 2014).

| Vegetables | Heavy metals | CR to Children | CR to adult |
|------------|--------------|----------------|-------------|
|            |              | GWI RWI DomWWI DrWWI | GWI RWI DomWWI DrWWI |
| **S. oleracea** | As | 9.4 × 10⁻⁴ 10⁻⁴ | 2.0 × 10⁻³ 10⁻³ | 3.2 × 10⁻⁴ 10⁻⁴ |
|            | Cd | 5.4 × 10⁻⁶ 10⁻⁶ | 4.4 × 10⁻⁵ 10⁻⁵ | 9.6 × 10⁻⁵ 10⁻⁵ |
|            | Pb | 3.9 × 10⁻⁷ 10⁻⁷ | 1.1 × 10⁻⁶ 10⁻⁶ | 1.9 × 10⁻⁶ 10⁻⁶ |
| **B. compestris** | As | 7.6 × 10⁻⁴ 10⁻⁴ | 2.8 × 10⁻³ 10⁻³ | 3.1 × 10⁻³ 10⁻³ |
|            | Cd | 1.6 × 10⁻⁵ 10⁻⁵ | 8.9 × 10⁻⁵ 10⁻⁵ | 2.2 × 10⁻⁵ 10⁻⁵ |
|            | Pb | 3.9 × 10⁻⁶ 10⁻⁶ | 1.8 × 10⁻⁶ 10⁻⁶ | 4.1 × 10⁻⁶ 10⁻⁶ |
| **R. sativus** | As | 6.7 × 10⁻⁵ 10⁻⁵ | 2.7 × 10⁻⁴ 10⁻⁴ | 1.4 × 10⁻⁴ 10⁻⁴ |
|            | Cd | 5.4 × 10⁻⁶ 10⁻⁶ | 3.5 × 10⁻⁵ 10⁻⁵ | 3.5 × 10⁻⁵ 10⁻⁵ |
|            | Pb | 4.5 × 10⁻⁷ 10⁻⁷ | 5.6 × 10⁻⁶ 10⁻⁶ | 1.5 × 10⁻⁶ 10⁻⁶ |
| **D. carota** | As | 1.4 × 10⁻⁴ 10⁻⁴ | 7.2 × 10⁻⁴ 10⁻⁴ | 3.0 × 10⁻⁴ 10⁻⁴ |
|            | Cd | 9.6 × 10⁻⁵ 10⁻⁵ | 5.8 × 10⁻⁵ 10⁻⁵ | 7.9 × 10⁻⁵ 10⁻⁵ |
|            | Pb | 1.6 × 10⁻⁵ 10⁻⁵ | 9.6 × 10⁻⁵ 10⁻⁵ | 2.9 × 10⁻⁵ 10⁻⁵ |
| **S. tuberson** | As | 6.7 × 10⁻⁵ 10⁻⁵ | 2.0 × 10⁻⁴ 10⁻⁴ | 3.0 × 10⁻⁴ 10⁻⁴ |
|            | Cd | 1.9 × 10⁻⁶ 10⁻⁶ | 6.6 × 10⁻⁵ 10⁻⁵ | 5.5 × 10⁻⁵ 10⁻⁵ |
|            | Pb | 1.7 × 10⁻⁶ 10⁻⁶ | 1.4 × 10⁻⁵ 10⁻⁵ | 2.1 × 10⁻⁵ 10⁻⁵ |
| **P. vulgaris** | As | 4.7 × 10⁻⁴ 10⁻⁴ | 2.2 × 10⁻⁴ 10⁻⁴ | 4.4 × 10⁻⁵ 10⁻⁵ |
|            | Cd | 1.5 × 10⁻⁵ 10⁻⁵ | 1.9 × 10⁻⁵ 10⁻⁵ | 1.0 × 10⁻⁴ 10⁻⁴ |
|            | Pb | 3.1 × 10⁻⁶ 10⁻⁶ | 9.7 × 10⁻⁶ 10⁻⁶ | 2.3 × 10⁻⁵ 10⁻⁵ |
showed THQs lower than unity as the THQs for Cd and Pb of this study showed less than 1. Hu et al., (2017a) observed that excessive use of leafy vegetables leads to higher THQs for heavy metals under any irrigation system. As this investigation determined that \textit{S. oleracea} and \textit{B. compestris} has always exceeded under all irrigation system. This is may be due to higher transpiration rate higher uptake of metals along with water by wide leaf of these vegetables.

4.4.3. Hazard indexes (HI)

This study indicated the consumption of vegetables grown under DomWWI and Dr WWI systems with respect to heavy metals is not fit for children health. All the vegetables under these irrigation system showed surpassed HI than threshold 1. While, RW irrigated \textit{S. oleracea}, \textit{R. sativus} and \textit{D. carota} also crossed the limited value. However, GW irrigated \textit{S. oleracea} and \textit{B. compestris} and \textit{P. vulgaris} showed higher HI than unity. In contrast, for same vegetables consumption showed very alarming HI to children but with few degree lesser effects. The result of present study revealed that Leafy vegetables participated more than other vegetables under irrigation system. Many other studies like this investigation summarized the consumption of wastewater irrigated vegetables leads to higher HI (Alturiqi et al., 2020; Haque et al., 2021; Onyele and Anyanwu, (2018), Kumar and Thakur, 2018). Based on the previous studies it is concluded that higher contents of heavy metals posed carcinogenic and non carcinogenic effects to human especially to children.

4.4.4. Cancer risk (CR)

In the present investigation it was observed that arsenic posed a serious threat to human health. In almost all irrigation systems, all vegetables accumulate As to such extent that it can serious cancerous effects. While, Cd under drain and domestic showed cancer causing range. The consumption of heavy metals contaminated vegetables leads to higher CR values than threshold (1.0x10^{-4}) as determined by several studies (Antoine et al., 2017; Li et al., 2018; Liang et al., 2019).

5. Conclusion

The main purpose of this study was to estimate the food quality provided to the humans. To find the required results it is necessary to assess the quality of irrigaton system. It has been seen that all the vegetables of Lahore were brought to local markets from nearby towns and villages. The irrigation system for these vegetables has some variation, e.g. some vegetables were irrigated with ground water by means of tubewells, A large area of Lahore and sheikhupura is irrigated with river Ravi water similarly, fields attached to villages and other housing societies are irrigated with domestic waste water. However, Hudia drain wastewater is also a source of irrigation which receives ample amount of industrial effluents. As, Cd and Pb in these vegetables sample measured and compared to assess the health risk associated with each source of water. Contents of As, Cd and Pb were observed highest in drain water irrigated soil and in their respective vegetables as compared to ground and river water irrigated vegetables. Similar trends of Bioaccumulation factor were assessed under these irrigation system. Leafy vegetables were found to be more dangerous for health than other types of vegetables. However, Estimated daily intakes of each metal in each system of irrigation was observed far less than the maximum tolerable daily intake of these metals. But their incremental accumulating behaviour showed higher target hazard quotient than threshold(1). Consequently, it has been determined that HI of wastewater irrigated vegetables were also observed higher than threshold. In some cases As content in ground and river water irrigation had also contaminated the foods. HI of heavy metals contaminated vegetables for adult and children were also compared and it was found that far higher HI values in children than adult made our concern more stronger. Present study also assessed that As content is reached to highly alarming level that it can cancer in different parts of body because its CR values were recorded highest and more than threshold (1.0x10^{-4}). While other metals were almost in safe range in terms of carcinogenic factors. So more investigation is needed in future to assess the health risk associated with heavy metals contaminated vegetables.

Authors contribution

NH, A. and MSA have contributed in the research idea and design, data gaining, and experimental analysis and explanation of data. While, K.S.A and A. J. contributed in the sampling and statistical analysis of data.

Ethical approval

There is no ethical conflict of interest.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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