International Journal of Ecology and Environmental Sciences
www.ecologyjournal.in
Online ISSN: 2664-7133; Print ISSN: 2664-7125; Impact Factor: RJIF 5.28
Received: 15-01-2021; Accepted: 30-01-2021; Published: 23-02-2021
Volume 3; Issue 1; 2021; Page No. 328-332

Heavy metals uptake by leafy vegetables grown across railway lines of Mumbai and nearby suburb's using irrigated wastewater

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Abstract
The leafy vegetables *viz*, Spinach, Lal Chauli, and Methi randomly collected from agricultural fields across the railway track of Central, Western and Harbour lines of Mumbai local trains at six different locations, were analyzed for heavy metals *viz*., Fe, Zn, Cd, Cr, Cu, Mn, and Pb using atomic absorption spectrophotometer. The heavy metal concentration was higher over year by year by using urban waste water used for irrigation use.

Concentration of Iron content shows higher values in vegetable plants followed by Zinc, Manganese, Nickel, Copper, Chromium and Lead content. Spinach has higher transfer factor for the heavy metals among the three vegetables followed by Lal Chauli and Methi. Highest transfer factor is recorded for zinc metal followed by manganese. Lowest transfer factor is recorded for chromium and lead. It would be strongly recommended that consumption of vegetables by irrigated with wastewater should be restricted and continuous monitoring of vegetables from such sites should be carried out. Constructed wetland and natural plant based technology can be implemented to treat the wastewater and treated water can be used for vegetable farming, that will have very less or no impact on human after consumption of vegetables grown from such irrigated sites.

Keywords: atomic absorption spectrophotometer, constructed wetland, natural plant based

Introduction

Raw sewage is widely used on agricultural lands in peri-urban areas of developing countries to meet water shortages. The problem linked with the final disposal of sewage and municipal waste is an important aspect of water pollution which should be considered in the context of wider environmental problem (Kanwar and Sandha, 2000) [11]. Municipal sewage/wastewater is an important alternative source of water for irrigation practices in metro or growing cities. The use of sewage water has been continuously used from the decades as a low priced fertilizer due to the rich in organic matter, NPK and other micronutrients (Hundal and Sandhu, 1990) [8]. Contaminated water is one of the major causes of diseases. Wastewater contains a diversity of pathogens and pollutants. No doubt that the use of untreated wastewater for irrigation poses a high risk to human health for all age groups. However, the degree of risk may vary among the various age groups. Untreated wastewater irrigation leads to relatively higher prevalence of hookworm (Feenstra *et al*., 2000) [5], and Ascarias infections among children's (Habbari *et al*., 2000) [7]. World Health Organization (WHO, 2006) [20] documented extensive studies on human health risks through sewage/wastewater irrigation, especially from pathogen contamination.

Irrigation with wastewater may lead to transport of heavy metals to soils and may cause crop contamination affecting soil flora and fauna. Some of these heavy metals that may bio-accumulate in the soil and others such as e.g., Cadmium (Cd) and Copper (Cu), may be redistributed by soil fauna such as earthworms (Kruse and Barrett, 1985) [13]. Wastewater mixed with river water has been used for crop irrigation for decade to decade, indicate that polluted water irrigation may account for up to 31 % of soil surface metal accumulation and that can lead to heavy metal uptake by alfalfa (Assadian *et al*., 1998) [3].

Heavy metals are harmful because of their non-biodegradable nature, long biological half lives and their potential to accumulate in body parts. Most of the heavy metals are extremely toxic due to their solubility in water (Arora *et al*., 2008) [15]. Wastewater contains considerable amounts of heavy metals that are harmful to human health and also to environment (Singh *et al*., 2004) [19]. Heavy metals are simply accumulated in the edible parts of vegetables, as compared to grain or fruit crops (Mapanda *et al*., 2005) [14]. Serious health problems can develop as a result of excessive uptake of heavy metals through vegetables. In addition, the consumption of heavy metal via contaminated food can deplete some of the essential nutrients in the body causing a decrease in immunological defences, intrauterine growth retardation, impaired psycho-social behavior, disabilities associated with malnutrition and a high prevalence of upper gastrointestinal cancer (Arora *et al*., 2008) [15]. The vegetables are rich in important minerals, carbohydrates, proteins, vitamins and trace elements which have marked health effect (Arai *et al*., 2002) [2]. Heavy metal contamination in green leafy vegetables grown in Bangalore Urban District were assessed and shows contamination of heavy metal found in two leafy vegetables *viz*., palak (*Spinacia oleracea*) and coriander (*Coriandrum sativum*). Study reveals that the consumption of these contaminated leafy vegetables may lead to increased health hazards (Jayadev *et al*., 2013) [10].

Methods and Materials

Study Area

Area selected for assessment is Central, Western and Harbour lines of the Indian Railways near the tracks. A background survey of this area was conducted to identify locally grown vegetables and their marketing area. Based on field survey, it was observed that Spinach (*Spinacia oleracea*), Lal Chauli (Amaranthus sps), Radish (*Raphanus sativus*), Methi/fenugreek (*Trigonella foenum*), Dhania (*Coriandrum sativum*) are grown on large scale. These vegetables are sold in market areas of Mumbai, Thane, Vashi, Kalyan and Dombivli. The agricultural plots are irrigated with wastewater flowing through open channels from a diesel run pump which draws it from sewage water running besides the plot. Some Time wastewater channels contain industrial wastewater which can be seen as reddish brown with foul smell.

This study was conducted from October 2018 to January 2019 along the Central and Western lines of the Indian Railways. Two samples collected from Western, one from Harbour, and three from Central lines near Rail Track and the location are shown in Table 1.1. Also, control sample (all vegetable) purchase from Vashi market

Table 1: Samples collected from Railway track of Western, Harbour and Central Lines

Sampling Sites	Area/Locations
W1(Western Line)	Mahim
W2 (Western Line)	Jogeshwari
H1 (Harbour Line)	Koperkharne
C1(Central Line)	Kurla
C2 (Central Line)	Bhandup
C3 (Central Line)	Takurli
CS (Control Sample)	Collected from Vashi Vegetable Market

Plant samples (n=6) were freshly collected and transferred laboratory by using HDPE (High Density Poly Ethylene) bags from the respective sites as mentioned in Table 1.1. Control samples are also collected from the Vashi vegetable market that is grown in Nashik to compare the results of other samples collected (Table 1.1). These samples were washed with distilled water and oven dried to weight constancy at 60°C for 48 hours. The dried samples were cut into small pieces, finely powdered, and kept airtight in PE Bags. Later 0.5 gms powdered samples were weighed and transferred to Teflon crucibles. These were mixed with 7 ml HNO_3 (65 %), 1 ml H_2O_2 (30 %), and microwave digested for 10 minutes at 220°C /1000 W). After digestion, the samples were filtered through a Whatmann filter paper No 42 and made up to 25 ml, stored in volumetric flasks and analyzed using ICPAES with multi-element standards.

Daily intake of heavy metals from vegetables

Daily intake estimates:

$$DIM = M \times K \times I/W$$

Where, DIM=Daily intake of metals, M=concentration of heavy metals in plants (mg/kg), K=conversion factor, I=daily intake of vegetables, W=average body weight.

Fresh weight of vegetables was converted to dry weight by using the conversion factor 0.085, (Rattan, 2005) [17]. The average adult and child body weights were considered to be 59.9 and 32.7 kg, respectively, while average daily vegetable intakes for adults and children were considered to be 0.345 and 0.232 kg/person/day, respectively.

Health Risk Index (HRI): The HRI for Cr, Ni, Cu, Pb, Cd, Mn and Zn by consumption of contaminated vegetables was calculated by following equation:

HRI=DIM/Rfd (Jan *et al*., 2010) [9]

Where, DIM=daily intake of metals, Rfd=reference oral dose. Rfd value for Cr, Ni, Cu, Pb, Cd, Mn and Zn is 1.5, 0.02, 0.04, 0.004, 0.001, 0.033 and 0.30 (mg/kg bw/day) respectively (US-EPA Integrated Risk Information System).

Results and Conclusion

The leafy part of the vegetables and irrigated water samples were collected from all six sampling sites and analyzed for physic-chemical parameters. The concentration of heavy metals in leafy vegetable was in the order of Fe>Zn>Mn>Ni>Cu>Cr>Pb respectively. The results of heavy metal concentration in vegetables are tabulated in Tables 1.2, 1.3 and1.4 respectively. Maximum and minimum concentrations of heavy metals are shown in Table 1.5.

Table 2: Values of Heavy Metal concentration for Spinach

Site Samples	Cu	Pb	Zn	Ni	Cr	Fe	Mn
W1	28.3	3.3	84	6.3	1.9	325	65
W2	26.3	2.3	55	8.5	1.6	362	52
H1	74.6	0.8	65	15.3	8.3	281	40
C1	18.3	1.4	86	13.6	1.2	350	36
C2	48.2	3.1	67	14.2	3.2	247	39
C3	66.5	3.3	45	7.6	4.1	269	41
CS	1.5	0.1	9.7	0.84	0.4	54.5	11

Note: All values in mg/kg of dry wt.

Table 3: Values of Heavy Metal concentration for Lal Chauli

Site Samples	Cu	Pb	Zn	Ni	Cr	Fe	Mn
W1	31.1	1.1	88.0	6.0	2.5	194	54
W2	33.6	1.5	45.0	5.2	2.9	225	71
H1	66.1	1.1	58.0	14.5	1.9	284	41
C1	15.3	2.2	45.0	14.1	1.2	312	29
C2	18.1	0.9	64.0	11.6	2.1	274	32
C3	22.6	1.5	47.0	8.3	3.1	280	45
CS	0.9	0.2	4.8	0.51	0.8	118	16

Note: All values in mg/kg of dry wt.

Table 4: Values of Heavy Metal concentration for Methi

Site Samples	Cu	Pb	Zn	Ni	Cr	Fe	Mn
W1	22.8	2.2	88	8.2	3.3	228	59.0
W2	36.3	1.3	56	10.6	2.9	298	79.0
H1	18.4	1.5	91	14.6	10.2	314	58.0
C1	19.3	1.2	104	16.3	14.3	241	30.2
C2	20.1	2.2	87	8.5	8.8	211	55.0
C3	33.3	1.5	79	6.6	2.8	301	28.0
CS	1.1	0.2	5.5	0.44	1.1	44	17.0

Note: All values in mg/kg of dry wt.

Table 5: Maximum, Minimum and Mean Concentration Values of Heavy Metal

Heavy Metals	Max	Min	Mean	SD	CV
Cu	74.6	15.3	33.3	18	55.4
Pb	3.3	0.8	1.8	0.8	44.4
Zn	104.0	45.0	69.7	19	27.2
Ni	76.0	5.2	14.4	16	110.1
Cr	8.3	1.2	2.4	1.7	69.4
Fe	362.0	194.0	277.6	47	16.8
Mn	79.0	28.0	47.5	15	31.6

All values in mg/Kg except SD and CV
SD-Standard Deviation
CV-Coefficient of Variation

In this assessment, the values of Cu, Pb, Zn, Ni, Cr, Fe, and Mn concentrations calculated as 11.3, 6.4, 69.7, 14.4, 7.0, 277.6, and 47.5 in mg/kg respectively in vegetable samples (edible parts) were depicted on Table 1.6 and Figure 1, which was higher than the average control values (CS). The obtained values of heavy metals varied greatly depending on the vegetable species in this analysis.

Table 6: Comparison of Observed Values with Control Values of Heavy Metal

Heavy Metals	Observed Values	Control Values (CS)
Cu	33.3	1.2
Pb	1.8	0.2
Zn	69.7	6.7
Ni	14.4	0.6
Cr	2.4	0.5
Fe	277.6	72.3
Mn	47.5	14.7

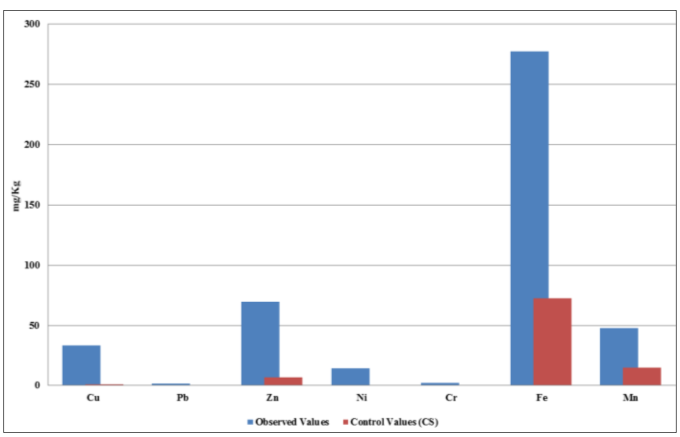

Fig 1: Observed Values and Control Values for Heavy Metals in Vegatable

Copper (Cu) is an important micronutrient which functions as a biocatalyst, required for body pigmentation. Nevertheless, most plants contain the amount of Cu which is insufficient for ordinary development which is typically guaranteed through artificial or organic fertilizers. The level of Cu content was recorded in range between 70.1 mg/kg to 15.3 mg/kg. Cu maximum concentration 74.6 mg/kg was recorded in Spinach and lowest 15.3 mg/kg was seen in Lal Chauli. This concentration exceed control values limit 1.2 mg/kg. However, all the vegetables in terms of Cu concentration did not elevate the safe limit as compare to control sample.

Lead (Pb) is a dangerous element that can be unsafe to plants, even with the fact that plants more often than not indicate capacity to gather a lot of lead without obvious changes in their appearance or give way. In various plants, Pb collection can exceed a few hundred times the edge of most extreme level reasonable for human utilization. This can be associate with long-term exposure to Pb may bring about harmed to central nervous system, delayed response times and decreased capacity of comprehension, while in kids, Pb may bring about behavioral disturbances and also learning and focus troubles. Industries can be attributed to become a source of Pb (Funtua, 2014) [6]. Higher and lower values of Pb observed as 3.3 mg/kg (Spinach) and 0.8 mg/kg (Methi) respectively. Average concentration values of Pb are found to be 6.4 mg/kg which is higher than the control values 0.2 mg/kg.

Zinc (Zn) are additionally one of the micronutrients basic for development of normal plant, still just a little amount of these components is required particularly Zn (25-150 μg/g). Zn is the slightest lethal and a basic component in human eating regimen as it is required to keep up the working of the immune defense. The Zn content was measured in range of 104 mg/kg to 45 mg/kg (Table 1.4). Zn maximum concentration 104 mg/kg was recorded in Methi and lowest 19.5 mg/kg was seen in Lal Chauli. These concentrations exceed average of control value 34.3 mg/kg. Regular consumption of these three vegetables may assist in preventing the adverse effect of Zn deficiency which results in retarded growth and delayed sexual maturation because of its role in nucleic acid metabolism and protein synthesis.

Nickle (Ni) is a poisonous heavy metal. Its range was between 16.3 mg/kg to 5.2mg/kg (Table 1.4). Ni maximum concentration 16.3 mg/kg was recorded in pumpkin and lowest 1.8 mg/kg was seen in brinjal. These concentrations exceed control value 0.6 mg/kg. These results are in close 1.20 and 0.775 mg/kg of Ni concentration in vegetables respectively (Shirkhanloo, 2015) [15].

Chromium (Cr): The level of Cr was in range 8.3 mg/kg to 1.2 mg/kg. Cr maximum concentration 8.3 mg/kg was recorded in spinach and lowest 1.2 mg/kg was seen in Lal chauli as shown in Table 1.4. In the present study, leafy vegetables showed the maximum level of heavy metals that may be linked with the high absorption rates of leafy vegetables having a large surface area. Garbage utilization in the agricultural land can be the source of heavy metals pollution in soil of our study area.

Iron (Fe) is a most fundamental element for every single living life form and is important for keeping up cell homeostasis. It is essential for the synthesis of chlorophyll and activates a number of respiratory enzymes in plants. The deficiency of Fe results in severe chlorosis of leaves in plants. High levels of exposure to Fe dust may cause respiratory diseases such as chronic bronchitis and ventilation difficulties (Pennington *et al*., 1995) [16]. Present study shows that level of Fe in vegetables was found in range of 362 mg/kg to 194 mg/kg. Fe maximum concentration 362 mg/kg was recorded in spinach and lowest 94 mg/kg was seen in Lal Chauli. These vegetables could be a good supplement of Fe but exceed the safer limit 72.2 mg/kg.

Results show that Manganese (Mn) range was recorded between 79.0 mg/kg to 28.0 mg/kg. Mn maximum concentration 65 mg/kg was recorded in spinach and lowest 28 mg/kg was seen in Methi. This concentration is much higher than control value 14.7 mg/kg.

Amin [1] reported Mn concentration in the vegetables ranged between 1.90 to 128.70 mg/kg. The factors responsible for the high content of Mn in vegetables were proposed to be the soil type and the application of agricultural pesticides and fertilizer (Chary, 2008) [4].

Daily intake estimates for adult and Child were calculated using average concentration values are shown in Table 1.7.

Table 7: Daily Intake Estimates for Adult and Child

Heavy Metals	DIM for Adult	DIM for Child	HRI
Cu	0.02	0.02	0.40
Pb	0.00	0.00	0.78
Zn	0.03	0.04	0.11
Ni	0.01	0.01	0.35
Cr	0.00	0.00	0.002
Fe	0.14	0.17	-
Mn	0.02	0.03	0.70

To evaluate the health risk related with these heavy metals, the HRI were ascertaining by partitioning every day intake of substantial metals by their reference dosages. HRI is generally approved to assess the health risk to risk materials in food. HRI<1 shows that the anticipated presentation is probably not going to posture potential health risk. However, a risk file >1 does not really demonstrate that a potential adverse health impacts will come about, so far just shows a high likelihood of posturing heath risk.

Conclusion

The well, healthy with balanced diet consist of having many servings of vegetables in a day but due to careless agricultural farming practices, this can be a reason for serious threat to human population. The urban farming sites irrigated with wastewater is the most unsafe ones but the sites that are also close to surrounding area with wastewater drains are also of significant consideration due to percolation of water. No significance difference was observed in copper and lead uptake by vegetables growing in sites irrigated with wastewater and those irrigated with ground water but are in close vicinity with wastewater drain. Over all it can be concluded that selected vegetables (spinach, lal chauli and methi) differ in their potential to accumulate heavy metals (Cu, Pb, Zn, Ni, Cr, Fe, and Mn). Vegetables like spinach have great tendency to accumulate higher concentration of Mn, Cr and Fe. This higher absorption of the said heavy metal might be linked with the high absorption rates of leafy. The regular consumption of vegetables grown in sites can cause harmful effects to the human population. It would be strongly recommend that consumption of such vegetables irrigated with wastewater from such types of sites should be restricted and continuous monitoring of vegetables from these sites should be done. Efforts should be made to amend the soil to reduce the uptake of metals in vegetable crops or these sites should be used for cultivation of non-food crops. Use of Constructed Wetland (Khan, 2015) [12] can be used for treatment of irrigated wastewater to reduce the concentration of heavy metals.

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