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RESEARCH ARTICLE

# UNDERSTANDING THE ASSOCIATION OF HEAVY METAL CONTAMINATION BETWEEN VEGETABLES AND ITS GROWING SOIL

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**ABSTRACT**

Heavy metals are natural constituents of the Earth's crust and trace amounts are always present in biological materials. They are defined more specifically as electropositive elements having a density greater than five. Through consumption of vegetable crops, dietary exposure to several heavy metals including Nickel (Ni), Cadmium (Cd), Chromium (Cr), Cobalt (Co), Lead (Pb), Arsenic (As), Mercury (Hg), Zinc(Zn) and Copper (Cu), has been recognized as a risk to human health. The study was carried out to understand the source and magnitude of heavy metal contamination in soil and various kinds of vegetables like potato, red amaranth us, spinach, carrot, cabbage, tomato and brinjal at Thane, Maharashtra where these vegetables are grown. The concentration of Lead (Pb) and Zinc (Zn) in the study area soil are higher than that of standard level. The Lead (Pb) in vegetables was found to be higher than the permissible limits of different International standards. Except lead, it is concluded that nearly all the samples did not exceed the Intentional Food Standards maximum level (ML). If contaminated soil and vegetables contribute to a progressive gathering of these metals in food chain there might possible to deep alternations of ecosystem with possible noxious effect on human health. Our study highlights that vegetables growing soil containing higher amount of metals that could be transferred into edible parts of the plant, so study area should be monitored regularly to avoid health risk of human being due to exposure of toxic level.



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## INTRODUCTION

Heavy metals are hazardous contaminants in food and the environment and they are non-biodegradable having long biological half-lives (Heidarieh *et al*., 2013). The implications associated with metal (embracing metalloids) contamination are of great concern, particularly in agricultural production systems (Kachenko, 2006) due to their increasing trends in human foods and environment. Metals most often found as contaminants in vegetables include As, Cd and Pb. These metals can pose as a significant health risk to humans, particularly in elevated concentrations above the very low body requirements (Gupta *et al*., 2008). So, the metals must be controlled in food sources in order to assure public health safety (WHO, 1995). Excessive amount of heavy metals in food cause a number of diseases, especially cardiovascular, renal, neurological, and bone diseases (Chailapakul *et al*., 2007). These metals could reach food chain through various biochemical process and ultimately biomagnified in various trophic levels and eventually threaten the health of human.

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The contamination of soil and vegetables by heavy metals is also a global environmental issue. They are ubiquitous in the environment through various pathways, due to natural and anthropogenic activities (Wilson, 2007). Under certain environmental conditions metals may accumulate to toxic concentration and they cause ecological damages (Jofferies, 1984; Freedman, 1989). Source of anthropogenic contamination include the addition of manures, sewage sludge, fertilizers and pesticides to soils, several studies identifying the risks in relation to increased soil metal concentration and consequent plant uptake (Whatmuff, 2002; McBride, 2003). Both commercial and residential growing areas are also vulnerable to atmospheric pollution, in the form of metal containing aerosols. These aerosols can penetrate the soil and be absorbed by vegetables, or alternatively be deposited on leaves and adsorbed. Analysis of vegetables grown in locations close to industry has reported elevated levels of heavy metals contamination (Kachenko, 2006; Voutsa *et al*., 1996) studied the impact of atmospheric pollution from industry on heavy metal contamination in vegetables grown in Greece. The results of the study indicated significantly higher levels of metal accumulation in leafy vegetables as compared with root vegetables.

This partitioning of Cd is well known, with accumulation of greater concentrations in the edible leafy portions of crops, than the storage organs or fruit (Jinadasa, 1997; Lehoczky, 1998). As the present study area is free from industrial pollution, the major sources of soil contamination with heavy metals might be due to the waste water irrigation, solid waste disposal, sludge applications, vehicular exhaust and agrochemicals. Excessive accumulation of heavy metals in agricultural soils through the use of agrochemicals and by other sources may not only result in soil contamination but also lead to elevated heavy metal up-take by vegetables and thus affect food quality and safety (Muchuweti *et al*., 2006). Heavy metals are easily accumulated in the edible parts of leafy vegetables, as compared to grain or fruit crops (Mapanda, 2005). Vegetables take up heavy metals and accumulate them in their edible (Bahemuka, 1991) and inedible parts in quantities high enough to cause clinical problems both to animals and human beings when they consume these metal-rich plants (Alam, 2003). Intake of toxic metals in a chronic level through soil and vegetables has adverse impacts on human, plants and the associated harmful impacts become apparent only after several years of exposure (Bahemuka, 1991; Ikeda, 2000). However, the consumption of heavy metal-contaminated food can seriously deplete some essential nutrients in the body that are further responsible for decreasing immunological defences, such as intrauterine growth retardation, impaired psycho-social facilities, disabilities associated with malnutrition and high prevalence of upper gastrointestinal cancer rates (Iyengar, 2001; Türkdoğan *et al*., 2003). In this study we investigated the concentrations of As, Pb, Cd, Ni, Mn, Co, Cu, Fe, Zn, and Hg in both soil and vegetable crops within vegetable growing region of Thane, Maharashtra; and evaluated their contamination status with respect to EU and international food standard guidelines.

## MATERIALS AND METHODS

**Sampling site:** Soil and plant samples were collected from 6 sites within four regions across Thane-Thane, Maharashtra (Figure 1). The soil samples were collected from six sites within four regions (Thane, Kalwa Railway Station, Kalyan Railway Station and Thakurli Railway Station and the vegetable samples from the Kalyan Railway Station and Thakurli Railway Station field of Thane District. The following vegetables are considered for heavy metals investigation: potato, red amaranthus, spinach, carrot, cabbage, tomato and brinjal Thane District (Figure 2).The sites were a mixture of commercial vegetables farms and private residential vegetable gardens.

**Soil and vegetable sampling:** Soil samples were collected from one side of the Ulhas River within 0-7 km and locations were maintained at about 1 km distance from one sampling point to another. The samples were about 500 g in weight. Immediately after collection, the samples were placed in the polythene bag which were washed with deionized water repeatedly for 3 times and taken to the laboratory as soon as possible. In the laboratory, the collected soil samples were dried in electrical oven at a temperature around 90°C to remove the moisture and then homogenized in mortar-pestle and reduced size to a fine powder. On the other hand, the collected vegetable samples (about 500 g) were thoroughly washed with fresh water in order to remove the adhering dirt and finally with deionized water. Then approximately 10 g of each sample were taken to a mortar for grinding to obtain a homogenous mass. Finally, the samples were taken to the small airtight polythene bags and then kept to the refrigerator for further analysis.

**Chemicals and equipment used:** Individual standard solutions (Spectro Pure, USA) of target elements were supplied by Varian Inc, USA with highest purity level (99.98%), supra pure nitric acid, potassium iodide and hydrochloric acid were purchased from E. Merck, Germany; sodium borohydride (Acros Organics, USA). All other chemicals were extra pure or supra pure received from E. Merck, Germany. The analytical instruments used in this study were Flame Atomic Absorption Spectrometer (FAAS), Varian Analytical Instrument, model Varian AA 280Z (Zeeman AAS) for Ni, Cr, Cd, Co, Cu, Pb, Fe, Zn and Mn. On the other hand, Cold Vapor Atomic Absorption Spectrometer (CVAAS), model ANALYTIK JENA (novAA350) for Hg and Hydride Generation Atomic Absorption Spectrometer (HGAAS), model AA 240 for arsenic determination. A microwave accelerator reaction system (Model No: MARS 5) was used for the digestion of the samples.

**Digestion of soil and vegetable samples for metal analysis:** To determine the concentration of heavy metals in soil and vegetable samples, aliquot (about 0.3 g) amount of the ground dried samples were taken in a vessel (Model no XP-1500) of the microwave oven where 4 ml of concentrated HNO3 was poured. The heating program employed was the one proposed in the user's manual. The three steps temperature programs were applied - 180°C with a ramping time of 10 min; holding time 15 min and cooling time 10 min. After completion of digestion, it is necessary to cool down rotor at a temperature of 60°C and then after cooling, loosen the upper screw of the vessel carefully with a torque wrench to release pressure under fume hood. The samples thus obtained were filtered and leveled up to the mark with deionized water in a 10 ml volumetric flask. Finally, the samples were examined with AAS for heavy metals estimation.

**Experimental procedure for metals determination:** The working standard solutions were prepared for heavy metal determination except arsenic and mercury by diluting a stock solution containing 1000 ppm of single element Atomic Absorption Spectrometer (AAS) grade standard with ultra-pure water. Cold Vapor Atomic Absorption Spectrometer (CVAAS) technique was used to determine the concentration of mercury (Hg) in the samples. 4 ml of the digested sample from the mother stock was taken in a test tube; 1 ml concentrated hydrochloric acid (HCl) and 15 ml de-ionized water was added into it as modifier for Hg. There were two chambers, reductant chamber with 0.3% diluted solution of NaBH4 and 0.1% diluted solution of sodium hydroxide (NaOH) and another was hydrochloric acid (HCl) acid chamber with 3% concentrated HCl. The wave length of mercury was 253.7 nm. 2 4=Hydride Generation Atomic Absorption Spectrometer (HGAAS) technique was used to determine the concentration of arsenic in the samples. 2 ml of digested sample was taken in attest tube; 3M concentrated HCl with a flow rate of 7 ml/min and 1% diluted solution of KI, 1% of diluted solutions of ascorbic acid were added into the test tube for arsenic as modifier with reaction time 3.5 hr. The total volume of the liquid sample was 20 ml. The wave length of arsenic was 193.7 nm. The standard solutions of mercury and arsenic and other heavy metal's standard solution were used to construct the calibration curves with the help of AAS.

Quality assurance measures included the calculation of method detection limit, inclusion of recovery and analysis of standard reference material. A blank reading was also taken and necessary correlation was made during the calculation of concentration of different elements.

## RESULTS AND DISCUSSION

**Total element analysis of soil:** The level of heavy metals in the soils was compared to the Indian Standard (Awashthi, 2010; European Union, 2000; Codex Alimentarious Commission, 1996; WHO, 2000; WHO, 2004). The guidelines identify ecological investigation levels (EILs), based on total metal concentration, considerations of phytotoxicity. The results of heavy metals concentration in the soil samples are presented in (Table 1). It was found that the Hg in the sampling station was below the detection limit (<0.03 mg/ kg) and the concentration of Ni, Cu, Cd, Pb, Cr, Co were below the permissible limits recommended by Indian Standard Awashthi and European Union, (Awashthi, 2000; European Union, 2000; Codex Alimentarious Commission, 1996; WHO, 2000; WHO, 2000) respectively which were shown in the Table 1. Whereas, the concentration of the zinc in the same soil samples were found in the ranged from 40.708 mg/kg to 448.469 mg/kg. The highest concentration of zinc (448.469 mg/kg) was observed in the soil of Thane Railway Station and the lowest amount of zinc was (7.639 mg/kg) was found in Kalyan Railway Station. From the study we see that, the concentration of Zn (102.506 mg/kg and448.409 mg/kg) in Thakurli Railway Station and Thane is higher than that of the permissible limit (50-100 mg/kg) recommended by WHO and Encyclopedia of Environmental Science. So, it can be concluded that the soils of Thakurli Railway Station and Thane Railway Station contaminated by zinc. Although the soil of Kalyan Railway Station is heavily contaminated as compared with Thakurli Railway Station.

The concentration of arsenic (As) in the collected soil samples were in the ranged from 2700 mg/kg to 5460.060 mg/kg. The highest concentration of arsenic (5460.060 mg/kg) was found in the soil of Thane Railway Station and the lowest concentration (2700 mg/kg) was found in the soil of Thakurli Railway Station. The WHO permissible limit for arsenic in agricultural soils is 0.5 mg/kg (WHO, 2004). This limit of arsenic was exceeded by all the soil samples which were analysed. The soils of the study areas contain large amount of arsenic, which indicates that soils are polluted by arsenic. Therefore, it is assumed that the vegetables that are grown in these soils will absorb more arsenic from the soil and thereby polluted by arsenic. Plant arsenic concentrations tend to increase with increasing soil arsenic and then stabilize at some maximal value at higher concentrations in soil, which is alarming to the people of that area. The content of iron (Fe) was in the ranged from 11809.818 mg/kg to 25626.379 mg/kg. The highest concentration of iron (25626.379 mg/kg) was observed in the soil of Thakurli Railway Station and the lowest concentration was (11809.818 mg/kg) found in the soil of Thakurli Railway Station. The maximum allowable limit of iron recommended by WHO (World Health Organization) is 150 mg/kg. The concentration of iron was too much high in the study areas compare with the maximum allowable limit of WHO. The sources of iron, zinc and arsenic in the study area are mainly due to burning of fossil fuel and anthropogenic activities such as waste water irrigation, solid waste disposal and sludge applications.

So, from the above results, it is concluded that the soil of the study area was highly polluted by zinc, arsenic and iron; Thane Railway Station and Thakurli Railway Station are most polluted area. Therefore, as the plants in these areas usually uptake more amount of heavy metals, thereby these plants will certainly affect the human and other animals when these plants will intake by them.

**Total element analysis in vegetables:** The all metals concentrations are expressed on a plant fresh weight basis (FW). Metal concentrations calculated in a dry weight basis (DW) were converted to a FW basis by diluting the metal concentration according to the ratio of FW to DW. The results of heavy metals concentration in the vegetable samples are presented in (Table 2). The contamination of heavy metals in vegetables indicate that the concentration of Ni, Cd, Cr, Cu, Co, As (<0.1 mg/kg) and As (<0.03 mg/kg) were obtained below the detection limits; the concentrations of Fe, Mn, Zn were below the permissible limit recommended by WHO (26, 27) respectively which were shown in the Table 2.

Butonlytheconcentration of lead (Pb) in vegetables was found in toxic level. Which were varied from 0.119 mg/kg to 1.596 mg/kg. The highest lead content was found in spinach (1.596 mg/kg) while in cabbage it was lowest in concentration (0.119 mg/kg). According to China food hygiene standard, 1994 the standard limit of lead for vegetables and fruit is 0.2 mg/kg while it is 0.3 mg/kg for WHO (Codex Alimentarius Commission. Joint FAO/WHO). It is found form Table 2 that in all vegetables except carrot, lead concentration is more than permitted level, so they are not suitable for consumption. In the study area lead concentration that was found in the vegetables is a result of human activities such as waste water irrigation, solid waste disposal and sludge applications, solid waste combustion, agrochemicals and vehicular exhausted. The lead in fuels can contribute to the air pollution. It is highly unlikely that in that region, the traffic is so voluminous that the air pollution could convert to soil pollution in short term. Lead is a toxic element that can be harmful to plants, although plants usually show ability to accumulate large amounts of lead without visible change in their appearance or yield. In many plants lead accumulation can exceed several hundred times the threshold of maximum level permissible for human (Codex Alimentarius Commission, 2001). The introduction of lead into the food chain may affect human health and may cause disruption of the biosynthesis of hemoglobin and anemia, rise in blood pressure, kidney damage, miscarriages and subtle abortions, disruption of nervous systems and brain damage. Thus, studies concerning lead accumulation in vegetables have increased important (Wierzbicka, 1995). From the overall study of the heavy metals in vegetables it has been found that the results obtained for different parameters investigated in each category of vegetable samples were at normal levels except lead, which is harmful for human. Thus, immediate actions are necessary to take to keep it within the permissible limit.

**Relationship of heavy metals in soil and vegetables:** Heavy metals bioavailability to plants is strongly related to the concentration and specification of the element in the soil solution because this is where the plants get the heavy metals that they take up. Typically, plants only take up one or two forms of heavy metals from the soil solution. The accumulation of metals from soils to plants depends on many factors such as metal forms, plant species and parts and soil properties.

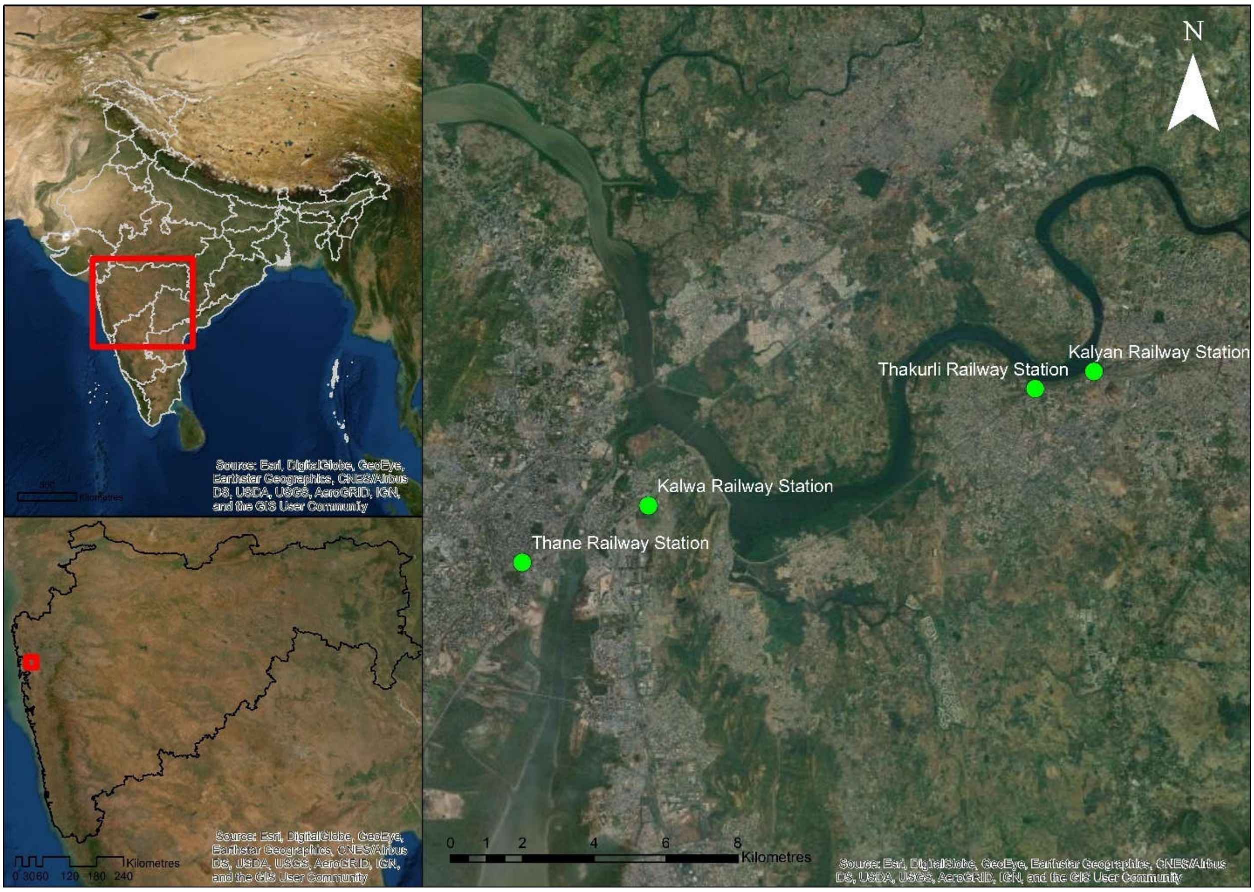


**Figure 1. The location of sampling region**

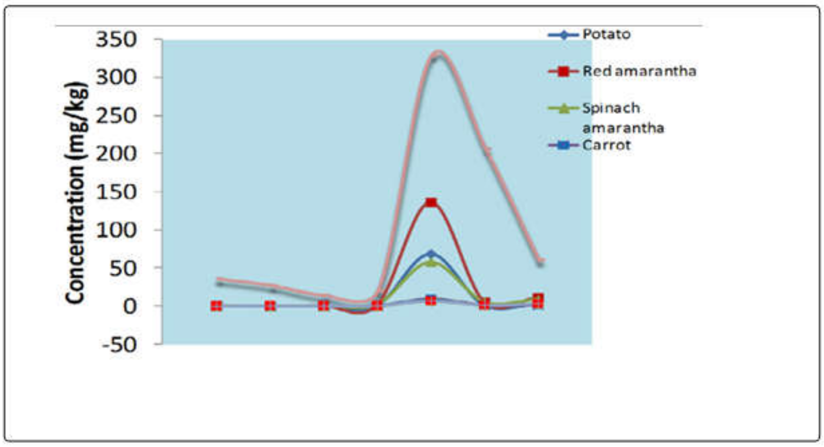


**Figure 2. Comparison of heavy metals content in vegetables and its growing soil (Thakurli soil).**

The solubility and consequently the plant uptake of the trace metals in the soils vary considerably with pH and the redox potential within the soil or the root system. The associated anion and the particle size also have a great influence on growth and metal uptake by plants. Uptake of heavy metals by plants tends to increase with increasing concentration, as long as it is within a certain range. When the concentration goes beyond the range the uptake will decrease because plant roots are injured, thus loading to a lower absorbing ability. Therefore, it is easy to make error if the soil pollution status of an area is determined simply from the contents of pollutants in the seeds. The enrichment factors quantify the relative differences in bioavailability of metals to plants and is a function of both soil and plant properties.

The present study showed that the concentrations of metals in vegetables were generally lower than that of the corresponding soils. This might be attributed to the root which seems to act as a barrier to the translocation of metals. In order to evaluate the accumulating capacity of heavy metals from soils to plant, a quantitative evaluation of the relationship between metals concentration in vegetable and in corresponding soils was made by calculating the transfer factor for the soil/plant system. Generally transfer factor varies from one plant to another plant, suggesting a selectivity of the plants in absorbing elements from soils.

**Soil-vegetable transfer coefficients:** The transfer coefficient quantifies the relative differences in bioavailability of metals to

**Table 1. The concentration of heavy metals in soil using FAAS, CVAAS and HGAAS analytical method**

| Metalsmg/kg | Soil 1 | Soil 2 | Soil 3 | Soil 4 | Soil 5 | Soil 6 | Standard |
|---|---|---|---|---|---|---|---|
| Ni | 36.774 ± 1.55 | 22.899 ± 0.65 | 18.277 ± 0.376 | 22.969 ± 3.343 | 15.051 ± 0.177 | 23.607 ± 5.353 | 75-150[a] |
| Cd | <0.1 | 0.806 ± 0.02 | 0.633 ± 0.036 | 0.387 ± 0.007 | 0.833 ± 0.012 | 0.467 ± 0.004 | 0.07-1.1 |
| Cr | 28.194 ± 0.17 | 17.1 ± 0.11 | 12.065 ± 0.326 | 17.567 ± 0.105 | 11.733 ± 0.035 | 15.333 ± 0.230 | 65[c] |
| Cu | 27.481 ± 2.09 | 14.935 ± 0.04 | 9.970 ± 0.556 | 54.326 ± 4.437 | 9.07 ± 0.472 | 12.849 ± 0.306 | 6-60[b] |
| As | 4200 ± 16.80 | 4346.667 ± 65.2 | 2700 ± 75.6 | 5460 ± 60.06 | 2940 ± 73.5 | 4353.33 ± 165.4 | 0.5[d] |
| Hg | <0.03 | <0.03 | <0.030 | <0.03 | <0.03 | <0.03 | - |
| Co | 15.129 ± 0.38 | 9 ± 0.207 | 7.748 ± 0.091 | 8.833 ± 0.141 | 7 ± 0.007 | 8.733 ± 0.183 | 10[c] |
| Pb | 21.290 ± 0.47 | 22 ± 0.440 | 21.290 ± 0.213 | 116.667 ± 0.233 | 116.089 ± 2.206 | 115.743 ± 1.620 | 10-70[b] |
| Fe | 25626.38 ± 1855.117 | 15491.539 ± 74.975 | 11889.922 ± 573.052 | 13569.992 ±1221.374 | 11809.818 ± 99.499 | 15720.552 ± 40.034 | 150[c] |
| Mn | 504.839 ± 1.5 | 317.822 ± 2.225 | 107.102 ± 2.142 | 307.333 ± 1.229 | 202.327 ± 0.6-7 | 261.578 ± 1.308 | 437[c] |
| Zn | 60.839 ± 0.27 | 102.506 ± 4.204 | 45.177 ± 2.077 | 448.469 ± 25.021 | 40.708 ± 0.032 | 42.003 ± 3.328 | 50-100[e] |

Soil 1 and 2 - Thakurli Railway Station; Soil 3 –Kalwa Railway Station; Soil 4 –Thane Railway Station, Soil 5 and 6 - Kalyan Railway Station.

[a]Indian standard awashthi and European Union, 2002;

[b]FAO/WHO, codex general standard for contaminants and toxins in foods, 1996;

[c]World Health Organization, 2000; [d]World Health organization, 2004;

[e]WHO and encyclopaedia environmental science.

**Table 2: Heavy metal concentration in vegetables using FAAS, CVAAS and HGAAS analytical method (32)**

| Metalsmg/kg | Potato | Red amaranthus | Spinach | Carrot | Cabbage | Tomato | Brinjal | Standard |
|---|---|---|---|---|---|---|---|---|
| Ni | <0.1 | 0.840 ± 0.01 | 0.54 ± 0.02 | <0.1 | <0.1 | 0.16 ± 0.01 | <0.1 | 1.5[a] |
| Cd | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | 0.1[b] 0.3[c] |
| Cr | <0.1 | <0.1 | <0.1 | <0.1 | 0.495 ± 0.01 | 0.75 ± 0.01 | 0.436 ± 0.01 | 2.3[b] |
| Cu | ND | ND | ND | ND | ND | ND | ND | 40[d] |
| As | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | 0.2[e] |
| Hg | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 | 10[d] |
| Co | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | 0.05-0.1[f] |
| Fe | 68.671 ± 4.53 | 136.3 ± 7.07 | 58.094 ± 1.3 | 8.824 ± 1.68 | 7.276 ± 0.14 | 6.444 ± 1.8 | 6.933 ± 0.708 | 425[b] |
| Mn | 1.22 ± 0.016 | 5.720 ± 0.017 | 5.280 ± 0.063 | 1.257 ± 0.014 | 0.99 ± 0.005 | 1.41 ± 0.001 | 1.446 ± 0.033 | 500[b] |
| Zn | 3.093 ± 0.643 | 11.305 ± 0.57 | 8.487 ± 1.171 | 1.206 ± 0.365 | 2.652 ± 1.228 | 2.818 ± 1.86 | 3.213 ± 0.983 | 60[e] |
| Pb | 0.377 ± 0.02 | 1.036 ± 0.01 | 1.596 ± 0.01 | 0.304 ± 0.01 | 0.119 ± 0.01 | 0.161 ± 0.01 | 0.465 ± 0.01 | 0.3[b] 0.2[g] |

[a]WHO/FAO (Codex Alimentarius Commission. Joint FAO/WHO, 2007) and Indian Standard Awashthi;

[b]WHO (Codex Alimentarius Commission, Joint FAO/WHO, 2001 and codex alimentarius commission, 1994); [c]European Union (EU), 2006; [d]WHO/FAO (FAO/ WHO, codex general standard for contamination and toxin in foods, 1996); [e]WHO (codex alimentarius commission, 1991);

[f]Agency for toxic substance disease registry (ATSDR, 1994a); [g]China food hygiene standard, 1994.

**Table 3. Transfer factors of heavy metal from Thakurli Railway Station soils into the vegetable samples**

| Metals | Ni | Cd | Cr | Cu | As | Hg | Co | Pb | Fe | Mn | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Potato | - | - | - | - | - | - | - | 0.017 | 0.003 | 0.003 | 0.037 |
| Red amaranthus | 0.016 | - | - | - | - | - | - | 0.048 | 0.006 | 0.014 | 0.138 |
| Spinach | 0.015 | - | - | - | - | - | - | 0.073 | 0.003 | 0.013 | 0.104 |
| Carrot | - | - | - | - | - | - | - | 0.014 | 0.0004 | 0.003 | 0.015 |
| Cabbage | - | - | 0.022 | - | - | - | - | 0.005 | 0.0004 | 0.003 | 0.033 |
| Tomato | 0.015 | - | 0.033 | - | - | - | - | 0.007 | 0.0003 | 0.003 | 0.035 |
| Brinjal | - | - | 0.019 | - | - | - | - | 0.021 | 0.0003 | 0.004 | 0.039 |
| Maximum | 0.016 | - | 0.033 | - | - | - | - | 0.073 | 0.0003 | 0.014 | 0.138 |
| Minimum | - | - | 0.019 | - | - | - | - | 0.005 | 0.0006 | 0.003 | 0.015 |
| Mean | 0.008 | - | 0.026 | - | - | - | - | 0.039 | 0.00045 | 0.0085 | 0.077 |

plants and is a function of both soil and plant properties. The coefficient is calculated by dividing the concentration of a metal in a vegetable crop (DW) by the total metal concentration in the soil. Higher transfer coefficient represents relatively poor retention in soils or greater efficiency of plants to absorb metals. Low coefficient demonstrates the strong sorption of metals to the soil colloids (Coutate, 1992). Soil-to-plant transfer is one of the key components of human exposure to metals through food chain. Transfer Factor (TF) or Plant Concentration Factor (PCF) is a parameter used to describe the transfer of trace elements from soil to plant body and it is also is a function of both soil and vegetables properties. The transfer coefficient was calculated by dividing the concentration of heavy metals in vegetables by the total heavy metal concentration in the soil (Kachenko, 2006).

$$TF = \frac{C_{plant}}{C_{soil}}$$

Where, $C_{plant}$: metal concentration in vegetablet issue, mgkg$^{-1}$ and

$C_{soil}$: metal concentration in soil, mg kg$^{-1}$.

In the present study, the TF of different heavy metal from soil to vegetable are presented in Table 3. Higher transfer factors reflect relatively poor retention in soils or greater efficiency of vegetables to absorbs metals. Low transfer factor reflects the strong sorption of metals to the soil colloids (29). The TF or PCF value ranges were: Cr0.019-0.033, Pb 0.005-0.073, Fe 0.0003-0.0006, Mn 0.003-0.014 and Zn0.015-0.138 and the trend of TF for heavy metal in vegetable samples studied were in order: Zn>Pb>Cr>Mn>Fe. The mobility of metals from soil to plants is a function of the physical and chemical properties of the soil and of vegetable species, and is altered by innumerable environmental and human factors (31). The highest TF value was found 0.077 and 0.039 for Zn and Pb. These might be due to higher mobility of these heavy metals with a natural occurrence in soil (Alam, 2003) and the low retention of them in the soil than other toxic cations (Zurera, 1987). According to the soil to plant transfer factor (TF) calculated for tested metals and leafy vegetables consumed by local residents, it can be concluded that Pb and Zn was high accumulator among the investigated metals. However, the higher concentrations of these heavy metals are due to the waste water irrigation, solid waste disposal and sludge applications, solid waste combustion, agrochemicals and vehicular exhausted.

### Conclusion

The present study reveals the determination of the heavy metals in soil and vegetables. The result clearly indicates that some heavy metals like Zn, Fe, As and Pb have been build up in soil and thereby in plants mainly vegetables are responsible for contamination. But without the above four heavy metals contamination, the soil and vegetables in the study area were found to free from other heavy metal contamination. So, the soil in these areas is quite safe for cultivation and also the vegetables are safe for eating. But dietary intake of these vegetables results in long-term low-level body accumulation of heavy metals and the detrimental impact becomes apparent only after several years of exposure. Thus, this study area is one of the more vegetables growing areas in Thane. So regular monitoring of these toxic heavy metals in soil, in vegetables and other food materials is essential to prevent excessive build-up in the food chain. Therefore, the main objective of this study was the assessment of heavy metals (Ni, Cd, Cu, Co, Pd, Fe, Mn, Zn, As, Hg) speciation in soil and vegetables in Thane area. Finally, the result thus presented in this paper is the only database available for the specification of heavy metals in soil and vegetable samples of this study area that will certainly help in better resources management, contributing to the effective monitoring of both environmental quality and will also provide information for background levels of metals of this studied area.

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